PEARL

The Journal of HEREDITY

VARIATION IN LEAF-SHAPE OF PAPAYA

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A Herd of Cattle Inbred for 20 Years
Brown and Silver Deer Mice
"Perennial" Sorghum for Breeders
A Yellow-Fat Gene in Sheep
Resemblances of Siamese Twins

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The American Genetic Association

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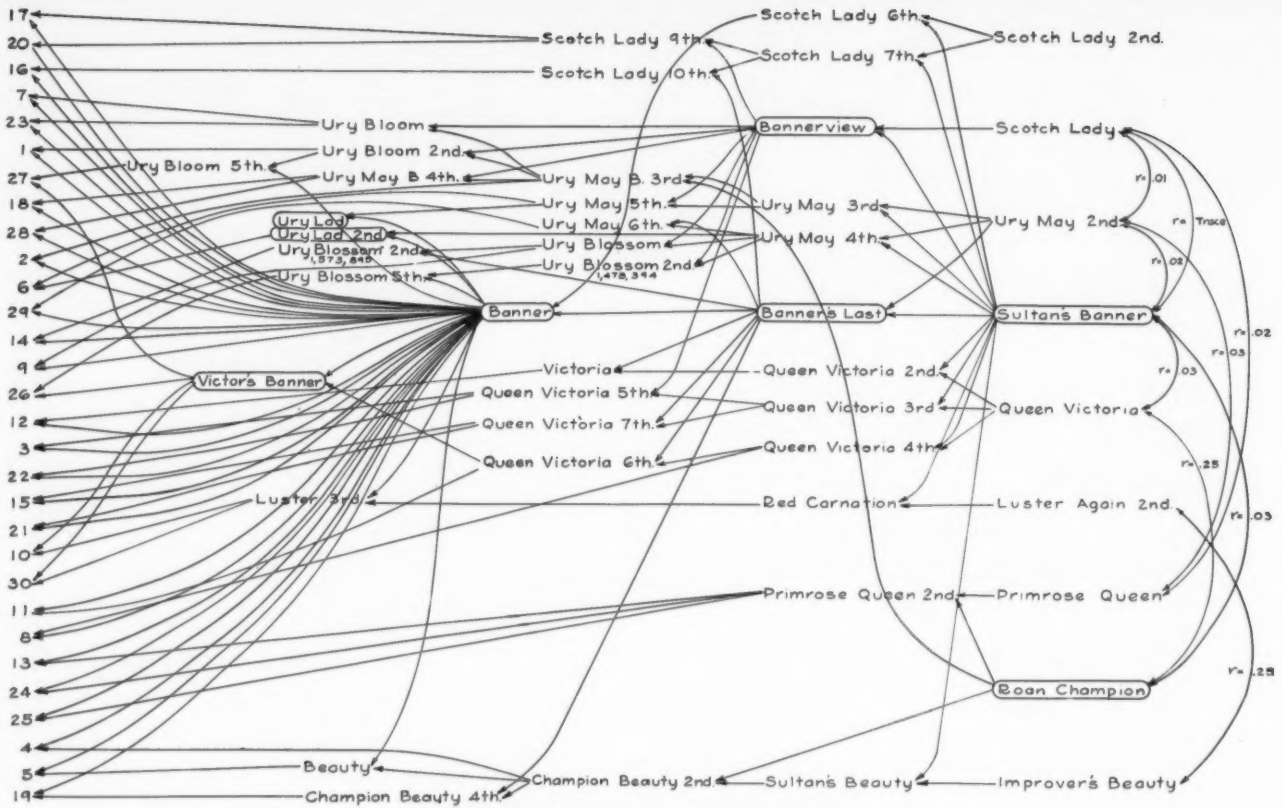


FIVE GENERATIONS OF INBREEDING

Frontispiece

Pedigree of the entire young herd late in 1932 complete back to the time of Sultan's Banner, and with coefficients of relationship (*r*) based on the ancestors alive in or near 1900. Each animal is shown but once. If it has more than one son or daughter, an additonal arrow indicates that. Selection has not yet had much opportunity to thin out the young herd. When that inevitable culling takes place many of the lines from Banner will disappear. In the herd ten or fifteen years from now, even though the present plan is continued, Banner may not appear much more important than Bannerview or Banner's Last. In any case he is not apt to be more important than those two combined.

A HERD OF CATTLE BRED FOR TWENTY YEARS WITHOUT NEW BLOOD

JAY L. LUSH
*Iowa State College**

THE steers in the champion county group of Shorthorns at the Club Show at the Iowa State Fair in 1931 were remarkably like each other. They proved to have come from the same herd and were all by the same sire, out of dams closely related to each other and to that sire. The herd from which they came had been bred for nearly twenty years without the purchase of any cattle, with the exception of one bull in 1915, most of whose descendants were later discarded. This breeding policy is so unusual that a description of it may be interesting to the readers of this JOURNAL, especially as the results so far have been at least as successful as those of the average purebred herd following a more usual policy. The plan has much in common with that described† in a Belgian draft horse stud in Iowa, but there is no connection between the two.

Story of the Herd

The herd was established in 1905 by the father of the present owner, Mr. Burt Neal, of Mt. Vernon, Iowa, who furnished the pedigrees and other information which made this analysis possible. There was nothing unusual about the breeding policy in practice until 1912, when Mr. Neal and his father attended a Shorthorn sale and saw there a bull calf (named Sultan's Banner) which as an individual pleased them so well that they purchased him, although his price was more than twice what they had intended to pay. When they looked up his pedigree after they had decided to buy him they found him to be a grandson of the noted Whitehall Sultan.

Sultan's Banner was placed in service with no deliberate intention of making any permanent change in the breeding policy of the herd. When his daughters came of breeding age the Neals liked them but, following their previous policy, looked for another unrelated bull in order to avoid the dangers of inbreeding. For this purpose, in 1915, they bought the bull Roan Champion. However, they liked the calves of Sultan's Banner more and more as time went on and began to wonder whether they could find another bull which would work still further improvement or even hold the excellence that they had in the offspring of Sultan's Banner. The calves of Roan Champion did not seem quite equal to those of Sultan's Banner and for that reason a plan for linebreeding to Sultan's Banner was evolved which would retain his influence in the herd and still would avoid the dangers of too intense inbreeding. With some hesitation they selected Bannerview, a son of Sultan's Banner, for tentative use on the daughters of Sultan's Banner. The calves from this mating seemed nearer to their ideal than those from the Roan Champion outcross. Later, Banner's Last, another son of Sultan's Banner, was selected for use on the daughters of Bannerview to replace Sultan's Banner when the latter finally died. Following Banner's

*Journal Paper No. J133 of the Iowa Agricultural Experiment Station, Ames, Iowa.

†Pearson, P. B., and Lush, Jay L. 1933. A Linebreeding Program for Horse Breeding. JOURNAL OF HEREDITY, 24:185-191.

PAST AND PROSPECTIVE HERD SIRES

Figure 1

Above is shown Banner at six years of age and below Victor's Banner as a three year old. Banner is the sire of practically all the herd now calves or reaching maturity. Victor's Banner will probably be the next major sire of the herd. Banner is the double grandson of Sultan's Banner, the foundation sire of this herd. His get have been shown at the International Livestock Show in Chicago in 1931 and 1932, ranking as high as third and fourth in the latter year. In local livestock shows his sons and daughters have won many prizes. All of them are of course rather closely related to him, but the coefficient of inbreeding has been held down by the use of two herd sires in the two preceding generations.

Last, a son of his out of a daughter of Sultan's Banner was placed in service and is still being used extensively, although by now a large proportion of the cows are his daughters or half sisters as well as being various kinds of cousins or grandnieces to him through his sire (Banner's Last) or his uncle (Bannerview) or his double grandsire (Sultan's Banner). Several young bulls are now being used tentatively to find some which will be suitable for future herd sires when Banner dies.

The breeding history therefore is that of a herd entirely closed to outside blood since the purchase of Sultan's Banner in 1912, except for the use of Roan Champion beginning in 1915. Only three daughters of Roan Champion have been retained in the herd and still have descendants there. No male descendant of his has yet been used as a herd sire. Hence the tendency has been to lose much of the inheritance introduced by the Roan Champion outcross, to "dilute the Roan Champion blood," many breeders would express it.

Possible Consequences of This Breeding System

Is it inevitable that such a breeding policy will lead to a highly inbred herd within an average human lifetime or less? It seemed to the writer that this might not necessarily follow, particularly in a herd where two bulls were usually maintained in service at all times. Consequently the pedigrees of the herd were investigated to see how high the inbreeding had already become and how uniform the herd had probably become in its inheritance. The farm was visited in November, 1932, and the pedigrees of all calves and yearlings there present were studied to give a fair picture of how far the breeding policy of the herd had gone by about 1931 or 1932. The pedigree of the entire herd as computed in this manner is shown in the Frontispiece. Each of the calves and yearlings in the herd is designated by a number.

All their ancestors are shown by name as far back as the time of Sultan's Banner. A few cows and two-year-olds actually in the herd in 1932 may not be included here because they happened not to have calves or yearlings alive in the herd then.

The entire herd is descended from two bulls (Sultan's Banner and Roan Champion) and seven contemporary cows. Three of those foundation cows have not had any male descendants saved for use in the herd and inheritance from them can be present only in eight of the 30 calves. There is considerable chance that eventually all their descendants may be eliminated entirely from the herd, as has already happened to the descendants of other cows which were in the herd at the time Sultan's Banner was introduced. The voluntary culling has been based mostly upon individuality with little attention to pedigree lines or breeding systems. The pedigrees of the nine foundation animals were traced back to 1900 to see how they were related to each other. Except for the fact that Roan Champion was a half brother to Queen Victoria and that two of the cows were paternal half sisters to each other, only a smattering of relationship was thus found. The relationships among the nine foundation animals are shown as correlation coefficients in the Frontispiece. The foundation group seems to have been selected not for any particular pedigree reasons, but largely because of their individuality and availability. This confirms the history of the herd as Mr. Neal told it, stressing the fact that there was nothing unusual about the breeding system practised until the first attempts were made to use sons of Sultan's Banner on daughters of Sultan's Banner. The average relationship of the nine foundation animals to each other was less than two per cent. (This relationship and all

the relationship and inbreeding coefficients mentioned later are relative to the ancestors born about 1900, which may probably without much error, be assumed to have been a random sample of the Shorthorn breed in the United States in 1900).

The Herd of Today

The average inbreeding coefficient for the thirty calves and heifers is only 16.9%, which is but little more intense than that (12.5%) from a single generation of mating half brother and sister. There were included among the thirty the three daughters of Primrose Queen 2d with inbreeding coefficients of less than 1%. At the other extreme there was one animal with an inbreeding coefficient a little higher than 31.5%, produced by mating Banner to his own daughter out of a granddaughter of Sultan's Banner. Only seven animals out of the thirty had inbreeding coefficients higher than that produced by one generation of parent-offspring or full brother-sister mating. The averages show that inbreeding intensity may remain rather low for a long time in closed herds where more than one sire is kept in service at a time, a point which has long ago been demonstrated theoretically.

Mr. Neal expressed the interesting point of view that he hesitates to look up the pedigrees of most of his animals lest on the one hand he become frightened by the amount of inbreeding that might be there or, on the other hand, that he might become so intrigued by some rule or system which he might think he saw in the breeding that he would begin to follow this system and mate his animals by pedigree rather than by individuality.

Probably the best measure of the genetic uniformity which has come over this herd is the average relationship of these thirty calves and heifers to each other. This turns out to be 42.8%, which is approaching the relationship (50%) of full sisters* in a random bred stock. Probably the closeness of this relationship can best be grasped by comparing it with that which would obtain in a herd where no females were ever bought but where the males were always bought and were not related to each other or to the females on which they were used. Such a breeding policy (not uncommon as an ideal among breeders of purebreds) tends toward an *inter se* relationship of 33.3% as a limit. This Shorthorn herd has actually gone well beyond that limit and hence may be described without exaggeration as probably genetically more uniform than any herd could be without the use of some inbreeding.

The relationship of the present herd to the various foundation animals is shown in Table I. Nearly half of the inheritance in the present herd comes from Sultan's Banner and a third of the rest probably comes from the one cow Ury May 2d who was the dam of Banner's Last and was also an ancestor in the female line of twelve of the thirty calves and heifers. Scotch Lady 2d, principally through having been the granddam of Banner, has

*Most breeders still express the relationship between two animals, in those cases in which any attempt is made to express it numerically, by saying that they have such-and-such a "percentage of the same blood." For example they would say that full sisters have "100% of common blood." Because they neglect the chances for unlikeness inherent in Mendelian segregation, such figures exaggerate (often very greatly) the probable likeness of the two animals in their inheritance.

Wright's coefficient of relationship which gives an unbiased estimate of such likeness, so far as that is due to common ancestry rather than selection, unfortunately has not come into extensive popular use, mainly because its computation is generally considered to be too complicated, although in truth it is but slightly more complicated than the "percentage of blood" figure if the corrections for inbreeding intensity (usually very small) are omitted from Wright's formula.

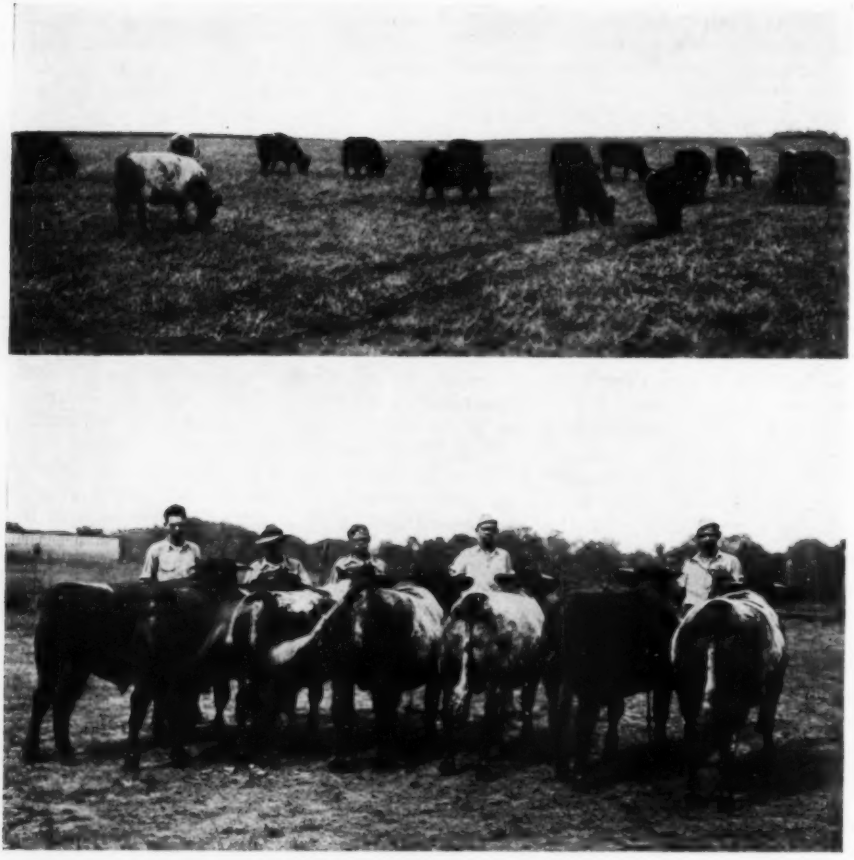
probably contributed about one-eighth of the genes now present in the herd. A somewhat smaller importance attaches to the bull Roan Champion and also to the cow Queen Victoria, who gave rise to so many daughters, granddaughters, and great granddaughters. Roan Champion is already less important than two of the cows and bids fair to diminish still more. Scotch Lady, through being the dam of Bannerview, has retained some importance for the herd today. The other three cows have had their relationship to the herd so lowered (since there was no linebreeding to them) that there is not much chance that their particular genes or gene combinations can still be abundant in the herd.

The bulls used subsequent to Roan Champion are related to all of the young herd today and the relationship is becoming progressively higher, although it still varies widely. The relationship of the present herd to the living bull, Banner, is distinctly higher than if he averaged being a sire or full brother to all of them. Perhaps this points toward the chief danger of such a breeding policy. Banner (Figure 1) has been used so extensively that now all of the herd is closely related to him. No son of Bannerview was saved. This heavy preference for the use of Banner means that, if the breeding policy is continued, the next bulls to go in service are certain to be sons of Banner. Hence in the next generation or two there will come a rather sharp increase in the total amount of inbreeding in the herd, nearly all of that being due to linebreeding to Banner. Had a son of Bannerview been saved, it would have been possible by his use to slow down the increase in inbreeding which now seems bound to occur as the result of Banner's having been used almost to the exclusion of all other sires during his lifetime. This heavy trend toward "concentrating Banner's blood" is not necessarily an undesired consequence, since Banner seems to be a good individual himself and his progeny have proved that he had an unusually desirable inheritance. However, it is most unlikely that his inheritance can be absolutely perfect and any intensive and long continued inbreeding to him is apt to make homozygous at least a few of the undesired genes which he may have possessed.

The breeding policy of the herd may be described roughly as having been almost that of a one-sire herd in the days of Sultan's Banner, then a two-sire herd when his sons were used, but it has narrowed down again

TABLE I. Inbreeding and Relationship Coefficients for 1931 and 1932 Heifer Calves

	Average	Range
Inbreeding	16.9	.6 to 31.5
Relationship of young herd:		
inter se	42.8	25.3 to 67.2
to foundation animals:		
Sultan's Banner	42.2	25.9 to 47.7
Roan Champion	9.3	1.4 to 25.7
Ury, May 2d	19.5	12.5 to 34.2
Scotch Lady 2d	12.3	5.6 to 23.2
Queen Victoria	7.2	1.4 to 29.7
Scotch Lady	5.3	.3 to 12.2
Primrose Queen	3.1	.4 to 25.3
Improver's Beauty	1.0	none to 12.1
Luster Again 2d	.9	none to 11.1
to later bulls:		
Bannerview	28.6	13.3 to 41.4
Banner's Last	46.0	32.1 to 61.8
Banner	61.4	44.5 to 72.2
Victor's Banner	50.0	36.7 to 71.1



VIEWS OF THE NEAL HERD

Figure 2

Above, a typical group of Neal cattle on late autumn pasture; below, the seven sons of Banner at the Wapsie Valley Fair in 1931. They won the first seven places in a class of twenty-eight at this local fair. The six on the right were taken to the Iowa State Fair and four of these went later to the International at Chicago. At the latter show two of them won third and fourth in a class of about eighty and another won ninth in an open class. These and other show ring winnings indicate that the herd is of high merit in the points which form the basis of show ring judgment.

almost to a one-sire herd during the time of Banner. The inbreeding rate in a one-sire herd is about twice as high as that in a two-sire herd and it may well be doubted whether even the wisest selection can keep enough control over a one-sire herd to make that an advisable policy even in a very good herd, except at rare times when one of those extraordinarily good sires a breeder sees but once or twice in a lifetime is available. Perhaps we are still too much afraid of inbreeding in cattle. Admittedly the solid base of experimental fact on which should rest a judgment about this is still scanty. At any rate the breeder's chance to keep perfect control is better in a two-sire herd than in a one-sire herd.

Show-Ring Experiences of the Herd

Only steers from the Neal herd have been shown in major show rings (i. e., shows larger than neighborhood and county fairs). In 1931 six steers were sent to the Club Show at the Iowa State Fair and four of these went on to the International at Chicago. At Des Moines the Neal boys showed them to individual winnings of 2nd, 4th, 7th, 8th, 14th, and 18th in classes of around 40 to 60 head each. Five of these steers constituted the champion county group of Shorthorns at Des Moines and third county group among all breeds competing. At Chicago in the Junior Show two of these steers won 3rd and 4th in a class of about 80. Another won 9th in an open class, and the group of three won third both in the Club Show and in the open show and fourth place in the open class for get of sire, all breeds competing. Presumably they were a fairly representative sample of the herd, for they (and one other not taken to Des Moines) were all the steer calves of proper age to be fitted for the 4-H Club Show. These seven had won the first seven places in a class of twenty-eight at the local (Wapsie Valley) show before six were taken to Des Moines. All seven were sired by Banner and were born in 1930. Five of them were full brothers to 4, 8, 9, 14, 18, and 28 shown in Figure 2. A sixth was out of a daughter of Sultan's Banner, not shown in pedigree chart. The seventh was "full brother in blood" to number 4 in pedigree chart. That is, he and 4 were by the same sire out of dams by the same sire and their maternal granddams were full sisters.

These show ring winnings are an indication that the herd is of high merit in the eyes of those who judge fat steers. These winnings would be more convincing if the herd had been shown in several different years. However, there is little reason except its unusualness to suppose that the excellent record of the steers in 1931 was due to a lucky combination of circumstances which could not be achieved again. Two more steers (one a full brother in blood to Number 4 and the other by Banner and out of the dam of Number 6 in Frontis.) were fitted for the Club Shows in 1932. They won first and second at the county fair and 4th and 8th in the individual class at Des Moines and were in the county group which was 3rd at Des Moines. Mr. Neal does not feel as yet that his Shorthorn experiment has progressed to such an extent that the knowledge and prizes which might be gained in show yard comparisons would pay him to fit a herd to show in the breeding classes on a prominent show circuit.

His Shorthorn herd is not Mr. Neal's major interest. Much of his interest and time are taken by his seed-corn breeding, in which he has for many years used the established methods of ear-row selection, progeny-testing, etc. He has not taken up the more recent methods of deliberate and intense inbreeding, selection of inbred lines, re-crossing those, etc. His Farm Organization activities receive more of his time and effort than his Shorthorns. It is partly because his Shorthorns are at least third or fourth in the attention they receive that he has not done more showing. Perhaps this also accounts for the breeding policy, which was not preconceived nor at any time very deliberately charted, but rather grew up as a natural result of a desire to hold the excellence of Sultan's Banner and a disinclination to go to much expense in order to follow current fashions in Shorthorn pedigrees.

Practical Considerations

The principles of genetics indicate that the average merit of the whole breed would be improved more rapidly than at present if there were dozens of good herds using some such policy as this to build distinct families among which other breeders might select or

which could be crossed with each other to find improved combinations, toward which linebreeding might be renewed. It is not so certain that the financial welfare of the individual breeders would be enhanced by such a plan. It automatically brings a considerable amount of isolation from fellow breeders. Many a prominent Shorthorn breeder even in this state does not know that the Neal herd exists, since it does not enter the breeding shows and Mr. Neal is never among the buyers at the sales from prominent herds. The reputation of the herd for being closely bred will still scare away a few potential customers who do not appreciate the prepotency of the inbred sire but have heard much and often of the defects apt to be uncovered by inbreeding.

At least partially offsetting these disadvantages should be noted the lack of expense for breeding stock, slight decrease in health risks due to failure to introduce outside stock or to send breeding animals on the show circuit, and some saving in travel, transportation and advertising costs which would be incident to a policy of keeping in constant touch with the leading herds of the breed and exchanging breeding stock with them. There is here an intricate balance between breeding and economic advantages and disadvantages which prevent any blanket decision that one breeding system is preferable to another under all conditions. The balance will turn one way in some cases and quite the other way in others. Much of the fascination in livestock breeding is due to the fact that each breeder's situation is unique. A different course of procedure is advisable in each case and there is always some uncertainty as to the wisdom of each decision until long after it is made!

Summary

A purebred Shorthorn herd in which almost no outside blood has been introduced for twenty years is described. In essence it was first almost a one-sire herd, then a two-sire herd and then a one-sire herd again.

This breeding policy was not deliberately planned but developed incidentally in an effort to conserve the good qualities of an outstanding sire by breeding his descendants together without extremely close inbreeding.

Twenty years after this sire was purchased the average relationship of the young herd to him remains at 42% but is less than 20% to any other foundation ancestor and the average inbreeding is only 16.9%. The maximum inbreeding in any animal is only 31.5%.

This is a practical demonstration that a moderate-sized herd may follow such a breeding policy for so long a time (full half of the active life of most men) with the average inbreeding still remaining low, with the merits of the early good ancestor reasonably well conserved, with the whole herd nearly as like each other genetically as ordinary full sisters, and with the herd still maintaining a reasonably high average of individual merit.

Simian Population Policy

"They (the inhabitants of the simian world, whose inheritance is curiosity and chattering) will *talk* about improving the race—they will talk about everything—but they won't use their chances to *do* it. Whenever a new discovery makes life less hard, for example, these heedless beings will seldom preserve this advantage, or use their new wealth to take more time thereafter for thought, or to gain health and strength or do anything else to make the race better. Instead, they will use the new ease just to increase in numbers; and they will keep on at this until misery once more has checked them. Life will then be as hard as ever, naturally, and the chance will be gone.

"They will have a proverb. 'The poor ye have always with you'—said by one who knew Simians."—DAY, CLARENCE, *This Simian World*.

THE EUGENIC VIEWS OF THOMAS JEFFERSON AND JOHN ADAMS

CHARLES O. PAULLIN
Carnegie Institution of Washington

THE Declaration of Independence affirms that it is a self evident truth "that all men are created equal." In penning this principle of the natural rights philosophy, Thomas Jefferson, the author of the Declaration, age in 1776 thirty-three, was doubtless reflecting the views of John Locke, with whose writings he was familar.

As one of the Signers, John Adams may be said to have endorsed the principle of the equality of all men. Since the Declaration is a political document, it would be unfair to hold that these two statesmen accepted this principle as a scientific truth, or even as a political truth not subject to qualification. However that may be, it is of interest to note the opinions that they expressed near the close of life, in the light of experience and mature reflection.

Beginning with 1812 and continuing until their death in 1826, Jefferson and Adams carried on a friendly correspondence in which they discussed such topics as politics, religion, history, aristocracy, the Indians, and the uses and abuses of grief. In two letters written in August and September, 1813, Adams quoted approvingly Theognis of Megara, a Greek poet and philosopher of the 6th century, B. C. His translation of the quoted passage is as follows:*

"My friend Curnis, when we want to purchase horses, asses, or rams, we inquire for the well-born, and every one wishes to procure from the good breeds. A good man does not wish to marry a shrew, the daughter of a shrew, unless they give a great deal of money with her. Nor does a woman disdain to be the wife of a bad rich man. But she prefers a man of property before a good man, for riches are honored; and a good man marries from a bad family, and a bad man from a good one. Wealth mingles races."

Adams commented significantly on this passage:

"Has science, or morals, or philosophy, or criticism, or Christianity, advanced, or improved, or enlightened mankind upon this subject, and shown them that the idea of the 'well-born' is a prejudice, a phantom, a point-no-point, a Cape Flyaway, a dream?

"I say it is the ordinance of God Almighty, in the constitution of human nature, and wrought into the fabric of the universe. Philosophers and politicians may nibble and quibble, but they never will get rid of it. . .

"The five pillars of aristocracy are beauty, wealth, birth, genius, and virtue. Any one of the three first can, at any time, overbear any one or both of the two last.

"Let me ask again, what a wave of public opinion, in favor of birth, has been spread over the globe by Abraham, by Hercules, by Mahomet, by Guelphs, Ghibellines, Bourbons, and a miserable Scottish chief, Stuart, by Zengis, by ——, by ——, by a million of others. And what a wave will be spread by Napoleon and by Washington! Their remotest cousins

*The quotations given below are from the *Works of John Adams* (1856), X, 58, 59, 64, 65-66, and the *Writings of Thomas Jefferson* (1904), XIII, 394-396.

will be sought, and will be proud, and will avail themselves of their descent. Call this principle, prejudice, folly, ignorance, baseness, slavery, stupidity, adulation, superstition, or what you will, I will not contradict you. But the fact in natural, moral, political, and domestic history, I will not deny, or dispute, or question.

"And is this great fact in the natural history of man, this unalterable principle of morals, philosopy, policy, domestic felicity, and daily experience from the creation, to be overlooked, forgotten, neglected, or hypocritically waved out of sight, by a legislator, by a professed writer upon civil government and upon constitutions of civil government? . . .

"You may laugh at the introduction of beauty among the pillars of aristocracy. But Madame du Barry says, *'la veritable royauté c'est la beauté,'* and there is not a more certain truth. Beauty, grace, figure, attitude, movement have in innumerable instances, prevailed over wealth, birth, talents, virtues, and every thing else, in men of the highest rank, greatest power, and, sometimes, the most exalted genius, greatest fame, and highest merit."

Jefferson's comments on Theognis are in a letter to Adams of October 28, 1813. They are of much interest, for they exhibit the patron saint of democracy as a believer in a natural aristocracy:

"The passage you quote from Theognis, I think has an ethical rather than a political object. The whole piece is a moral *exhortation* . . . and this passage particularly seems to be a reproof to man, who, while with his domestic animals he is curious to improve the race, by employing always the finest male, pays no attention to the improvement of his own race, but intermarries with the vicious, the ugly, or the old, for considerations of wealth or ambition. . .

"The selecting the best male for a harem of well-chosen females also, which Theognis seems to recommend from the example of our sheep and asses, would doubtless improve the human, as it does the brute animal, and produce a race of veritable. . . [aristoi].* For experience proves that the moral and physical qualities of man, whether good or evil, are transmissible in a certain degree from father to son. But I suspect that the equal rights of men will rise up against this privileged Solomon and his harem, and oblige us to continue acquiescence under the . . . [debasement of the city stock]† which Theognis complains of, and to content ourselves with the accidental aristoi produced by the fortuitous concourse of breeders. For I agree with you that there is a natural aristocracy among men. The grounds of this are virtue and talents. Formerly, bodily powers gave place among the aristoi. . .

"The natural aristocracy I consider as the most precious gift of nature, for the instruction, the trusts, and government of society. And indeed, it would have been inconsistent in creation to have formed man for the social state, and not have provided virtue and wisdom enough to manage the concerns of the society. May we not even say that that form of government is the best, which provides the most effectually for a pure selection of these natural aristoi into the offices of government? The artificial aristocracy is a mischievous ingredient in government, and provision should be made to prevent its ascendency."

*The word in brackets is the transliteration of an omitted word in Greek.

†The words in brackets are my translation of omitted words in Greek.

BROWN AND SILVER DEER MICE

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THE rearing of a number of generations of young mice produced by trapped specimens of *Peromyscus maniculatus* has resulted in the appearance of two well-marked coat colors which we are provisionally naming brown and silver agouti because they resemble brown and silver agouti *Mus*. The genetics of these coat colors has progressed to a point where the data give some degree of probability to the idea that each character is due to a pair of recessive genes, and that the genes for the respective characters are, as would be expected, non-allelomorphic.

Origin and Appearance of Brown Peromyscus

Brown specimens appeared first in the second generation produced by a brother-sister mating of cage-bred *P.m. gambeli* and were subsequently observed in more than one family of *gambeli-rubidus* F_2 hybrids. Since in all cases the brown young could be traced to a male *P.m. gambeli* trapped as an adult in sage brush at Silver Lake, Oregon, there does not appear to be much doubt that this specimen was heterozygous for the character.

The dorsal surface color of average brown specimens of *Peromyscus* is yellowish brown and therefore considerably lighter in color than that of brown agouti *Mus*, a specimen of which was kindly supplied to us for this comparison by Dr. E. F. Barrows, Oregon State Normal School, Monmouth. The distinctly yellower shade of brown *Peromyscus* which prompted its being reported at first as a yellow,† appears to be due not only to the presence of a greater amount of yellow pigment in the agouti band of the banded hairs in the pelage but also to lighter brown cortical pigment in all the hair tips.‡ The basal portion of the hair shafts of brown specimens of *Peromyscus* is not unlike that of *Mus*. There are the additional facts that all *Peromyscus* which we possess have a white ventral surface and therefore appear to be more like white-bellied than normal-bellied *Mus*, and that all our *Peromyscus* carry the agouti factor.

The tail stripe and such pigmented portions of the skin as the tips of the pinnae, the soles of the feet and the pigmented scrotal spot are brown in brown specimens. There is some individual variability in the color tone of brown mice although this individual variability is not as pronounced in this character as in Sumner's pallid mice or the silver agouti mice to be described below. A photograph of our original specimen in postjuvenal pelage together with a *P.m. rubidus* of the same age, chosen for the honor because it would pose, is presented in Figure 3*A*. Neither this brown gambeli nor his sibs proved to be fertile, the stock of browns we possess being all *rubidus-gambeli* hybrids. An adult brown female is shown in Figure 3*B*.

Inheritance of Brown

Table I itemizes the results of the

*This work has been assisted in the past by grants from the General Research Council of the State System of Higher Education, and is now being further subsidized by a grant from the National Research Council. The authors are considerably obligated by the subsidies from these two sources.

†Yellow *Peromyscus*, which appeared among both Sumner's and Collins' cage bred young are probably not comparable to yellow *Mus*.

‡We have recently obtained some brown young extracted from *rubidus* parentage which are much closer to brown *Mus* in general pelage color.

BROWN AND SILVER DEER MICE

Figure 3

A—Brown *P.m. gambeli* in post-juvenal pelage with a wild-type *P.m. rubidus* the same age (left). The short ears on the brown specimen are a familial not a racial trait. *B*—Adult brown *Peromyscus* female,—a *gambeli-rubidus* hybrid. *C*—Post-juvenal silver agouti male performing ablutions and exposing light basal pelage. *D*—Adult pale silver agouti female in feeding pose. Note pigmentation of edge of pinnae. This specimen's juvenal pelage was pale grey. *E*—Adolescent silver brown female ready to wash her face. Note paleness of both pelage and ears. *F*—Silver brown (left) and brown baby mice from the same litter brushing up for their photograph.

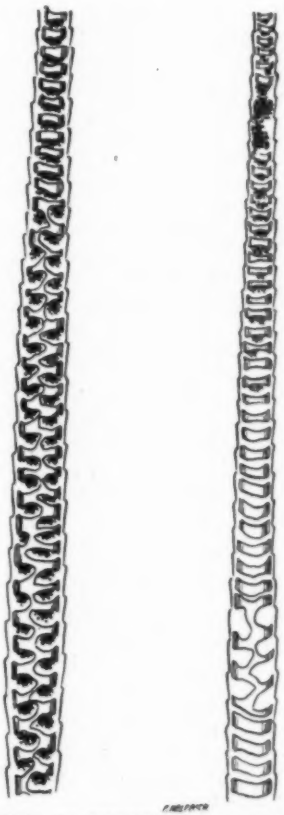
usual test matings made with a new character. In all but one kind of mating the data fit the interpretation that the brown color is due to the presence of two recessive genes. The percentage of browns obtained from back crosses, for the most part of heterozygous females to brown males, is substantially higher than expected. The average size of the litters in which this occurred was below that produced by mating other heterozygous animals *inter se;* 2.6 young per litter for back crosses as against 4.5 young per litter for heterozygous animals mated *inter se*. There may be some interrelation here, of small litters and the paucity of grey mice but we have no explanation for the cause of this other than the possibility of differential viability, and this is not very apparent in litters from other matings.

The brown mice have proved to be excellent experimental animals equal, in viability and fertility, to any stock we have used experimentally.

Origin and Appearance of Silver Peromyscus

Silver agouti mice were first observed in a litter of F_3 *gambeli-rubidus* hybrids. There is some appropriateness in the fact that all the silver mice trace back to a female trapped as an adult at Silver Lake, a locality which appears to have been rich in mutant genes.

The color difference is produced by a reduction in the amount of black pigment deposited in the proximal portions of a variable number of the hairs of the pelage. Pigment may fail to be deposited just proximal to the agouti band leaving the hair white from there to the base, or it may be merely diminished in amount for a certain length of the hair shaft, such portions alternating with others in which pigment deposition is fairly normal in amount. Rather typically pigment diminution or cessation is preceded by what may be interpreted as an abrupt increase in pigmentation



PIGMENT DISTRIBUTION IN HAIRS
Figure 4

Part of a normal and a "silver" hair (right) in the normally pigmented region just proximal to the agouti band. The "silver" hair shows a characteristic mass of pigment granules followed by rapid cessation of pigment deposition.

in the form of a large irregular lump or lumps. This involves distortion of the lacunae in this region of the hair and often of the hair shaft as well. The situation is illustrated in Figure 4 which is a drawing of the shafts, just proximad of the agouti band, of a normal and a "silver" hair. Figure 3*C* shows a postjuvenal silver demonstrating his light basal pelage.

The reduction in pigmentation is most complete in the earlier pelages

of a given individual, and appears to be more liable to occur in fur hairs than in overhairs. As reported by Dunn for silver agouti *Mus* the character varies considerably, in different individuals. In *Peromyscus* it varies from a condition in which the basal part of the coat is very white and the entire pelage pale silver grey to a condition indistinguishable from non-silver except upon microscopic examination of the pelage. A rather pale adult silver is shown in Figure 3*D*. In practice we examine hairs of the juvenal coat, under a low power binocular microscope, of all animals not obviously silver, looking especially for the "lumps" of pigment mentioned as a characteristic of the hair of silver animals. We have not carried the experiment far enough to estimate the accuracy of our methods of determination, and know that irregularities in pigment formation occasionally occur in mice that are probably not genetically silver.

Dunn and Thigpen[1] describe and figure "silver grey" and describe "silver brown" *Mus,* in which the paleness of the pelage is due to the presence of white and white-tipped hairs, their number increasing with age. Later in the paper the authors report the derivation of silver agouti *Mus* from the back cross of F_1 mice, produced by a silver gray × wild type mating, to silver greys. In these silver agoutis the silvering is due to the paleness of the hair bases, this paleness decreasing with age so that young silver agoutis may look like wild type specimens when they grow older. Our silver agouti *Peromyscus* resemble Dunn and Thigpen's silver agouti *Mus* in every particular mentioned.

A quite differently inherited character in *Peromyscus,* which Sumner has called "grizzled," is, in appearance, very like Dunn and Thigpen's "silver grey" *Mus* for the color depends in each case upon the presence of all white hairs interspersed among the pigmented hairs of the coat, and the number of all white hairs increases with age. We have a few grizzled mice and their pelages contain many all white but no "silver" hairs. Two litters of a grizzled × silver mating have produced five young, all of which are wild type so the difference between silver agouti and grizzled (agouti) *Peromyscus* is established in every particular. This still leaves us in some difficulty if we are to arrive at a parallel nomenclature in the two genera, for if Sumner's "grizzled" mice are genetically quite distinct from Dunn and Thigpen's "silver greys" the outward similarity and similar response to age of the two characters is rather surprising.

Inheritance of Silver

As may be observed in Table II, we do not have as many young from our series of matings of silver as of brown mice, having been hampered especially by the paucity of silver females. Tentatively we have identified the character as being due to two recessive genes, the effects of which are readily modified by other genes common in the stock we are using. The silver × silver matings have produced almost all male mice; 1 ♀ to 16 ♂. This may be due to the death, prior to identification, of silver females as well as to the possibility that the few females we have used in these matings are male-producing individuals. Our silver mice are quite fertile but not as vigorous looking or as robust as the browns.

As might be expected brown and silver proved to be non-allelomorphs and reciprocal matings of brown and silver individuals typically produce wild type agouti young, although one such animal exhibited some "silver" hairs. The double recessive silver browns, sensing perhaps the obligations incident to possessing the premier double color pelage to be figured in the genus,* prove to be very hand-

*Sumner's pallid-yellow and albino-pallid mice were pallid and albino, respectively.

some mice (Figure 3*E*). They average somewhat paler than either parental type for the black pigment of the hair tips which produces the darkest portion of silver pelages is reduced to yellowish brown while the pigment of the hair bases, which is the darkest portion of brown pelages, is reduced in amount or eliminated by the genes for silver. A difference between brown and silver-brown sibs is shown in Figure 3*F*.

Matings of F_1 animals as may be observed in Table III, have so far produced many more than the expected number of young mice identified as silver brown. While this may be due to chance we are testing the possibility that brown heterozygous silver animals are phenotypically silver brown. Unless this is so the number of silver brown animals we have makes it improbable that silver and brown are linked.

Summary

1. Two coat colors in the species *Peromyscus maniculatus* which may correspond respectively to brown and silver agouti *Mus* have been described.

2. Data were presented which indicated that each character is produced by a pair of recessive genes the effects of which are, in the case of silver agouti mice, rather variable or readily modified.

3. The difference between silver agouti and grizzled *Peromyscus* has been tested.

4. Brown and silver genes have been shown to be non-allelomorphic but their visual effects are to some extent supplementary.

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TABLE I

Mating		Wild type	Brown			
Brown × non-brown	obs.	212	....	exp.	212	....
Brown × brown	obs.	....	79	exp.	....	79
Brown × het. brown	obs.	17	35	exp.	26	26
Het. brown × het. brown	obs.	113	44	exp.	118	39

TABLE II

Mating		Wild type	Silver			
Silver × non-silver	obs.	63	1	exp.	64	....
Silver × silver	obs.	....	17	exp.	....	17
Silver × het. silver	obs.	25	27	exp.	26	26
Het. silver × het. silver	obs.	51	19	exp.	52	18

TABLE III

Mating		Wild type	Brown	Silver	Silver brown
Silver × brown	obs.	25	8	3	10
$F_1 \times F_1$	exp.	26	9	9	3

Greek Science

THE HEROIC AGE OF SCIENCE: The Conception, ideals and methods of science among the Ancient Greeks, *by* William Arthur Heidel. Carnegie Institution publication No. 442; Williams and Wilkins Company, Baltimore, 1933. 203 pp. Price $3.00.

QUOTING from the author, "the subtitle of this modest booklet is intended to indicate its scope." The booklet (although it has considerable meat for such a designation) is divided into two parts; Part one dealing with the Conceptions and Ideals of Science among the Greeks, and part two with methods. The second part is further subdivided into six sections; 1, Introductory; 2, Observation and Induction; 3, Classification;

4, Analogy; 5, Experimentation; 6, Epilogue.

In this brilliantly conceived and admirably written book Dr. Heidel shows that the Greeks used the same principles of science which are applied today. The virtual denial by many historians that the Ancient World had anything to show which might properly be called science, the author demonstrates, is due to confusion of what we mean by science. To judge Ancient science from our elevated standpoint is not only unfair but historically incorrect since at such a distance our vision is distorted. The view has been ably championed by Sarton that one must at least make an attempt to judge ancient science contemporaneously before one can properly evaluate it. The importance of a past civilization is determined not only as judged by our own standards but when seen in relation to its coexisting cultures. The student of ancient science may be compared to an aerial topographer. As such, however he often forgets that when looking at a terrain from a great height, the contours tend to flatten out. It is only by flying low that one begins to discern hills and valleys and other topographic details.

It is on a low flying expedition that Dr. Heidel takes us in his survey of Greek science. And from this vantage point we are shown quite clearly that the Greeks differ from us primarily in the crudity of the techniques employed. Our advances are due, not so much to the attainment of more valid principles, as in the refinement of method.

To this reviewer, by far the best portion of the book is the chapter on experimentation. In it Dr. Heidel proves conclusively the erroneousness of the view that the Greeks did not experiment. In well documented passages we are shown that they recognized and undertook the value of experiment and used the method. To cite a few examples, a Hippocratic treatise mentions the fact that blood coagulates and surrounds itself with a membrane when it cools undisturbed, but does not if stirred. In another Hippocratic work an embryological experiment is described: "Take twenty or more eggs and set them under two or more hens to hatch; then, beginning with the second day, until the last, on which it is hatched, taking one each day, open and examine it, and if you will find that all agree with my account as far as one may compare a chick with a man." And of course we cannot neglect Aristotle, who gave us probably our first careful study of chick embryology.

Credit for the first studies on the "insensible perspiration" is usually given to the Paduan physician Sanctorius (1561-1636). It is of considerable interest therefore to learn that in the Third Century B. C. Erasistratus sought by experiment to measure the amount of "insensible prespiration," by placing fowls in vessels and keeping them without food for some time, and weighing them at the beginning and end of the experiment. Including the excreta at the end, he found the loss of weight considerable. Examples could be multiplied drawing from the fields of physics and optics but this is not intended as an abtract of Dr. Heidel's book.

To find fault with this work is difficult, yet one fault could be mentioned. The author writes with an apologetic air for the shortcomings of the Greeks. Such an attitude is not strictly consistent with the content of the book for the outstanding feature of it is the magnificence of the Greek achievement which needs no apology. But this is only a minor criticism of a book which is really a model for further work in the all too little known field of ancient science.

MORRIS C. LEIKIND
Library of Congress

DOUBLE-DECK PAPAYA LEAVES AN EXAMPLE OF LEAF EVOLUTION

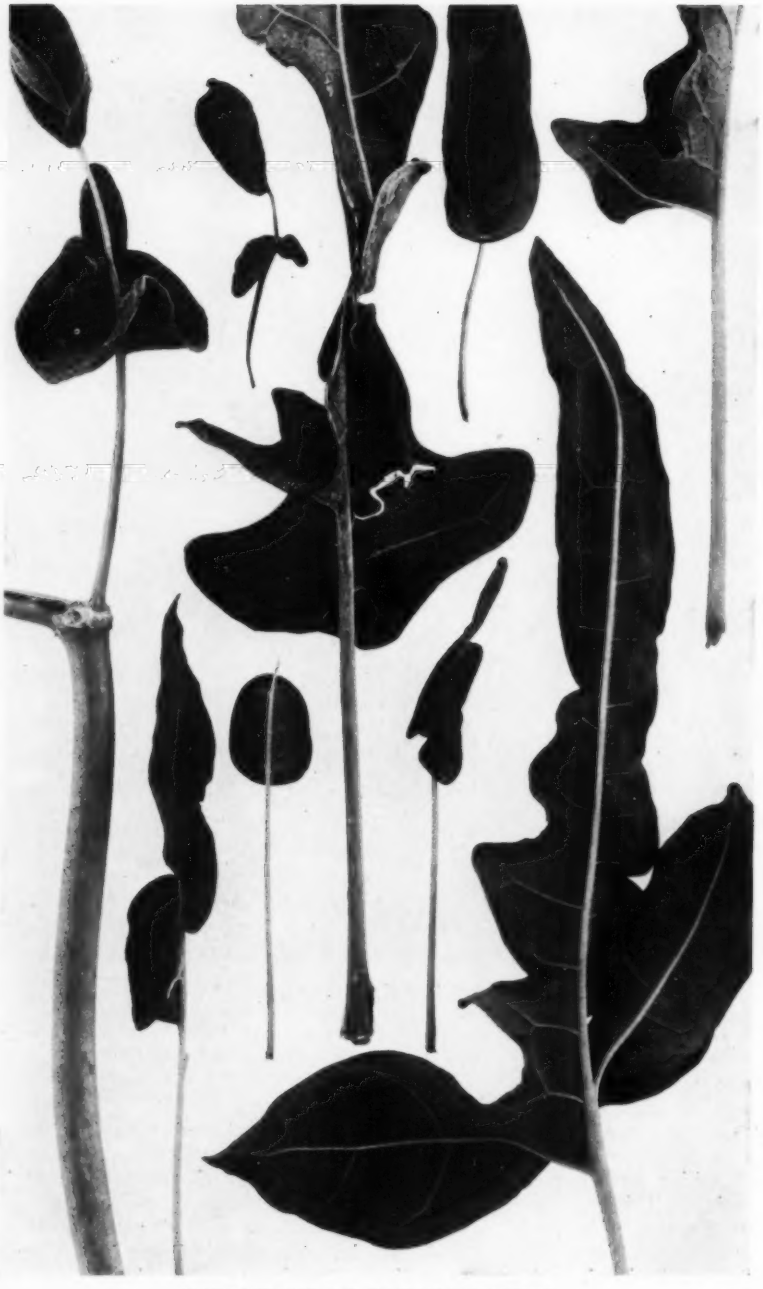
O. F. Cook
Bureau of Plant Industry

PAPAYA PLANTS IN FLORIDA

Figure 5

A commercial papaya planting near Coconut Grove, Florida, showing extremes of variation in narrow and broad lobing of leaves, also in spacing of leaf-scars on the stems.

THE papaya, sometimes known as the "melon-tree," is a familiar garden plant in tropical countries. It is grown commercially in southern Florida, and to a slight extent in southern Texas and in southern California. The plant is shaped like a palm, with a stout stem several feet high, bearing a terminal cluster of broad many-lobed leaves and large melon-like fruits. The milky juice of the fruit contains a digestive ferment, now of recognized medical value under the name papain. The fresh latex in a few minutes digests the skin of the fingers to the quick, and then smarts like a caustic.



VARIATIONS OF PAPAYA LEAVES

Figure 6

Secondary leaf-structures of nine double-deck (superate) leaves, showing different sizes and forms of the peculiar appendages standing on the top of otherwise normal leaves in this variation. At the left an appendage still attached to the callus of a leaf, with parts of the petiole and midrib, to show the upright position of the appendage. (Natural size.)

A small-fruited wild papaya, not uncommon in open forests and waste places in Central America and the West Indies, is referred to the same species as the cultivated plant (*Carica papaya*). Also in southern Florida, wild papayas with fruits only an inch or two in length are found in many places under native forest conditions. The so-called mountain papaya (*Carica candamarcensis*) comes from the cool valleys of the Andes, and apparently is adapted to coast conditions in California, near San Diego.

A striking variation was found in 1932 in an experimental planting of papayas in the Colorado River Valley of southern California. An otherwise normal leaf bore a secondary leaf-structure erected in double-deck fashion above the primary leaf-blade. The first sight of such a leaf gave a startling sense of novelty, though several plants in California were found to have such leaves, and many others in southern Florida. A superposed leaf-structure should not be confused with twinning, fasciation, or other lateral modifications of leaf-blades, which have been reported from several families of plants. The Carica variation may be described as a vertical addition to the leaf, supported by a secondary petiole growing out of the callus of the primary leaf-blade. (See Figures 6 and 7.)

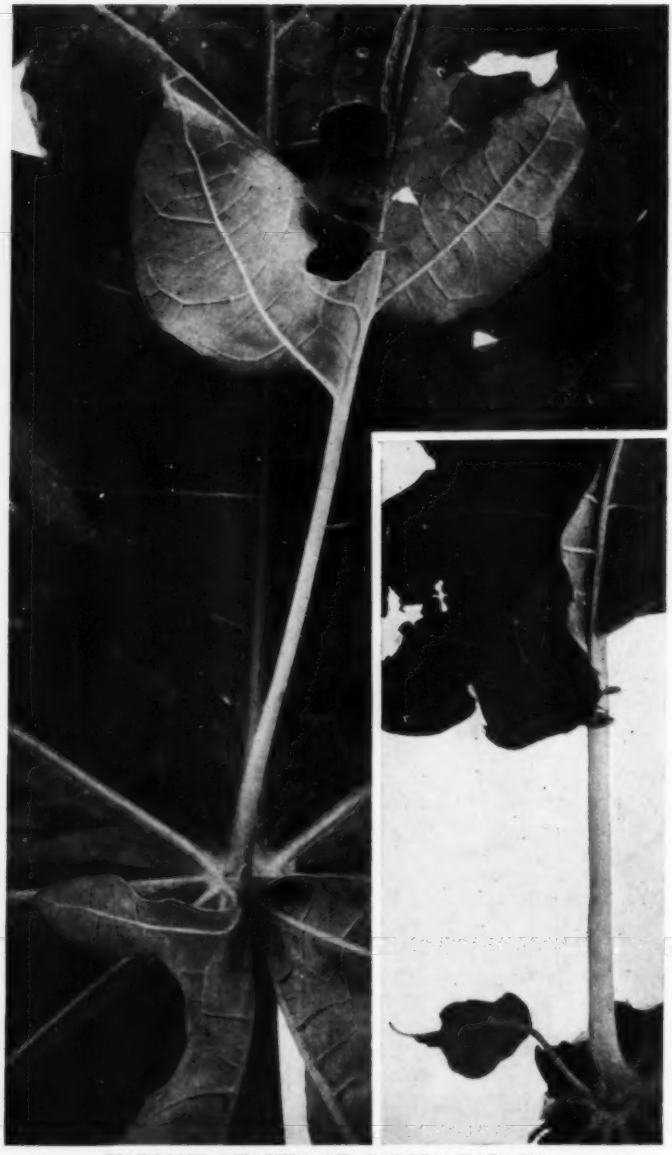
A special word seems necessary to characterize the overtopped, double-deck leaf, with a secondary leaf-structure rising above the primary leaf-blade. Such a word as *superate* may convey the idea of a leaf surmounted by another leaf, as representing the morphological principle of adding new elements of leaf-structure by superposition. Setting one leaf on another may be considered as a method of derivation of compound leaves from simple leaves. The Carica variation illustrates a constructive possibility in leaf evolution that apparently has not been recognized in the past, but may be worthy of observation and experimental study.

Forms of Secondary Leaf-Blades

The sizes and forms of the papaya leaf-appendages are extremely variable, ranging from very small appendages, only two or three inches long, with rounded or cupped blades, to those that are six or eight inches long, with large, leaf-like blades, commonly three-lobed, though usually irregular in outline, and often excised, interrupted, or distorted. (See Figures 6 and 7.)

The margins of some of the deformed secondary leaf-blades grow together above the midrib, in cup-like forms (ascidia), or the tips of the blades may be suppressed, leaving naked projections of the midribs (stylidia). In other cases folded surfaces of distorted leaves may grow together, thus placing a grooved strip of under-surface tissue on the upper surface of the leaf, surrounded by free margins, as on the appendage shown in Figure 7. Similar overset seams with reversals of tissue (syndetia) occur in cotton, as results of partial regenerations of leaf-tissues following tomosis injuries.[4, 7]

Most of the secondary blades of the variant papaya leaves stand nearly erect, with the midrib continued in the direction of the secondary petiole, but cases also occur, as shown in Figure 6, where the blade is separated into two or three sections, and in some of these the lower section appears more or less horizontal, or transverse to the secondary petiole. The different position of the lower section of the blade may mean that in these cases the secondary leaf-structure is double, in the sense of being formed of two successive sections. Three such sections may



VARIANT LEAVES OF CARICA PAPAYA

Figure 7

Central portions of two double-deck (superate) leaves, at the left with a large secondary leaf-blade borne on a secondary pedicel rising from the callus of the primary leaf-blade; at the right the callus of a leaf with two of the secondary leaf-structures, one much smaller than the other. (Natural size.)

be indicated in a drawing by Ernst[10] of a Carica variation in Venezuela.*

Some of the variant plants in Florida have short, sessile, spoon-shaped appendages, an inch or less in length, with the green upper side of the appendage faced backward toward the sinus. One or two small appendages may accompany a large appendage, (Figure 7, inset). No appendages were observed on the leaves of the wild papaya in Florida, which have the sinus more open, with two of the primary veins often becoming confluent along the margin, near the base of the sinus. The wild papaya leaves usually have only 9 lobes, in contrast with 11 to 13 lobes in the cultivated plant.

Derivation of Compound Leaves

The usual supposition has been that compound leaves were derived by subdivision of simple leaves, through gradually deepened incision and lobing of the leaf-margins, till separate pinnae were formed. Such courses of derivation may have been followed in many groups, though a different method is indicated in the walnut family by the occurrence of intermediate stages between the lower pinnae and the stipules of the bud-scales. Thus the lateral pinnae may be considered as expanded, reduplicated stipules, intercalated into the leaf-structure, leaving only the terminal pinna to represent the original leaf-blade. In the walnut family the foot element of the primitive leaf, rather than the blade element, seems to have furnished the larger part of the present leaf structure.[6]

The double-deck papaya variation shows that a third course of derivation of compound leaves is possible, by apical replication, thus erecting a new structure on top of an original simple leaf, instead of new sections being intercalated below the original leaf-blade. A further suggestion has appeared recently, of compound leaves being formed by reduction of branches, in a family of tropical trees, the Burseraceae.[12]

Specialized forms of branches occur in several families of plants, and in some of these cases both the leaves and the branches are definitely dimorphic. Branch characters and leaf characters may be variously combined or assimilated, as shown in the different dimorphic forms. These vegetative specializations have received little attention from morphologists, though relations to practical problems in breeding, adaptation and propagation of cultivated varieties have been recognized.[2,3]

Growth from Leaf-Structures

In the study of leaf-variations like those of the papaya, the nature of the plant organization must be considered. A replacement of branch characters by leaf characters is implied in the suggestion that compound leaves have been derived by reduction of branches, while other theories assume that leaves may become branch-like, either by parallel variation or by genetic assimilation of the characters.

The superposed secondary leaf of the papaya variation may be described in customary terms as a "proliferation" or "enation" of the primary leaf, or as an example of "regeneration" or "adventitious" growth, though objection could be taken to either of these designations as inadequate or misleading. Goebel is very emphatic in maintaining a fundamental distinction between the "permanent tissues" and the "vegetative points" of continued growth.

> The primordia of the leaves arise as *lateral outgrowths* on the vegetative points of the shoot-axis . . . . the leaf-primordia always proceed from embryonal tissue. There is no case known in which a leaf-primordium has proceeded from permanent tissue, although vegetative points of a shoot may arise from this in regeneration. So far as

*The term autophyllogeny is referred to Masters, Vegetable Teratology, 355 and 445. Several other terms, as polyphylly, pleiophylly, and phyllomania, have been proposed by Masters and other writers for describing abnormal leaf-structures, though none of these appears to be closely parallel to the papaya variation.

we know also there are no such things as adventitious leaves or parts of leaves...."[11]

Undoubtedly a tissue that gives rise to a new growth must have a germinal or embryonic character, though tissues that regenerate are not for that reason to be considered as more specialized, but rather as more primitive. The general course of specialization has been from reproductive to vegetative structures. It follows from the double-celled constitution of the higher plants and animals that their vegetative or somatic tissues were derived originally from reproductive tissues.[1, 9]

In Goebel's theory of morphology the stem or "shoot-axis" appeared as the primary feature of the plant structure, with the roots, leaves and floral organs as appendages. Hence, as Goebel says, "The arrangement of the leaves on the shoot-axis has attracted special attention." The systems of leaf arrangement (phyllotaxy) appeared as the central fact of the plant structure like the systems of crystal formation in chemistry. Likewise the plants that "regenerate" buds from the leaves have appealed to physiological investigators because they appeared as the only exceptions to the rule of vegetative points being limited to the shoot-axis.[13]

Leaves of Bryophyllum and related genera produce abundant offsets from the leaf-margins. Begonia leaves are completely "totipotent," so that even small fragments are able to form roots and vegetative buds, from which new plants can grow, as from seedlings. In Helwingia (Cornaceae) Erythrochiton (Rutaceae), Phyllobotrium (Flacourtiaceae), inflorescences are produced from midribs of leaves. In a case like Helwingia (Figure 8) there can be little doubt that the growth functions of axillary flower-buds are extended to the middle of the leaves, and the midrib is broader to the point of attachment of the flowers or fruits. The Carica variation may be considered as a partial retention of the function of vegetative reproduction in the callus at the base of the midvein, for which analogies may be found in the tobacco plant and many others that form buds along the midvein, though not in other parts of the leaf.

From an original implication of repair or replacement of injured or lost parts, the use of the term regeneration has extended among recent writers to the formation of new tissues or organs, as in the case of Bryophyllum, with an assumption that an evolution of regenerative function has taken place as an adaptive response to natural selection, though such a relation has not been established. Morgan canvassed these arguments and reached the conclusion that the data of regeneration "belong to the general category of growth-phenomena," so that no special physiological or evolutionary explanation would be required. "The fact that the process of regeneration is useful to the organism cannot be made to account for its existence in the organism."[14]

Leaves as Structural Units

The alternative of the shoot-axis theory is to consider the plant-body as a composite organization, with the several kinds of vegetative and reproductive metameters, the *"knoten"* of Goethe, as the structural components. Cells, tissues, and organs are the components generally recognized in plant morphology, while components of a higher order have been disregarded. Goethe recognized the correspondence of the floral organs and seed capsules to the leaves and stem-sections of the vegetative parts, and applied the sectional principle to the higher animals by way of homologies between vertebrae and skull-bones. Plants are segmented organisms like centipedes, insects, and other "articulate" animals. Study of the arthropod

groups may afford an approach to plant morphology.

The shoot-axis theory of the plant organization, with the leaves attached at the nodes and spaced by the internodes, gives an inverted idea of the structural relations, as though it were said of a railway train that the cars are connections for the couplers. The leaves are not attached at the junction-points as appendages of the stem, but develop with the stem-sections, as coordinate parts of the metamers. To recognize these structural relations, the term *caulomer* may be used to designate the stem-section of a metamer, and *phyllomer* for the leaf-section. In the floral envelopes and the reproductive organs only the phyllomers may be developed, and the caulomers suppressed. A term like caulomer is required in order to avoid the misleading implications that appear to be inseparable from the term *internode*.

Goethe undoubtedly was correct in his conception of the plant body as a series of equivalent units, and also in viewing the different forms of metamers as examples of evolutionary changes. His poem on plant evolution recounts the sequence of development, the simple seedling leaves, the gradually more incised, lobed or divided forms of the adult leaves, the reduced leaves and elongated stem-sections of the flower-stalks, and the metamers that are variously specialized as bracts, sepals, petals and essential organs of the flower—"Always the first structure, yet not always alike." The structural components of the plant were seen to have many gradations of smaller and greater differences, like the differences between the species. Two fundamental discoveries were made at the same time. The field of morphology was entered, and the study of evolution was begun. In seeing how the plants were constructed, Goethe saw also how the work of creation was accomplished. A new view of nature opened before him. *"Zum Erstaunen bin ich da!"*

The delay of more than a hundred years in appreciating Goethe's morphological and evolutionary discoveries is a strange chapter in the history of science. No poet had greater celebrity in his own life-time, but there was little response to his biological discoveries and a feeling of estrangement was voiced in his later years, of living in a world of ideas that he could not communicate. New paths of expression had to be opened before such a doctrine could gain currency. Evolution had no vocabulary, or even a word to name it, when Goethe wrote, but the Spirit of evolution was dramatized in *Faust*, "Weaving on the Loom of Time the living Garment of Divinity." The genius of that poem in the course of sixty years led the thought of the world into channels of scientific interest, so that Darwin's effort to explain evolution was not disregarded. The massive argument of natural selection filled the stage for the next half-century, leaving Goethe's pioneer achievement in oblivion. Although metamerism is a visible phenomenon, while causative effects of selection are entirely inferential, argument has led away from fact, as frequently happens.

Variations among Metamers

Variations among metamers, and changes of characters in passing from one kind of metamer to another, are the more significant of the nature of heredity because they occur with the same set-ups of the genes, or at least without the complications that attend the formation and conjugation of germ cells in producing new sexual generations. The metamers are not twins, but successive births by vegetative reproduction, like parthenogenetic generations of plant-lice. Each successive formation of a plant metamer is a separate repetition of the hereditary process, subject to

CURIOUS LEAF STRUCTURES

Figure 8

(*Above*). A papaya plant with numerous double-deck leaves, at Coral Gables, Florida, the secondary leaf structures large and expanded, of the same texture as the primary leaf.

(*Below*). *Helwingia japonica*, a shrubby plant of the cornel family, showing mature fruits borne directly on leaves, an example of structural assimilation of leaf and inflorescence characters. (Natural size.)

independent variation, and resulting in a distinct individual.[5]

Each type of metamer is the expression of a different set of characters. Definite numbers of metamers of the same type may be formed, and then the characters change abruptly to those of a different kind of metamer, as though by a process of mutation. Analogies may be seen between the transformations of metamers and the metamorphoses of insects. Abnormal organs are formed when the character-changes that should occur between successive metamers are deferred or advanced. Such misfit combinations (chimeric metamers) are seen when a part of a sepal shows petal characters, or a part of a petal shows sepal or anther characters.*

Large numbers of plant variations may be interpreted as intermediate stages between different forms of metamers, to which the name metaphanic variation has been applied. To see the metamers as different individuals, though associated as members of the same organism and able to vary among themselves in the course of their development in each generation, is to gain a broader view of the content of variation. An internal inter-organic range of variation is recognized, as the background of many differences between individuals. Not only the characters that appear in connection with particular metamers need to be considered in the study of variation, but also the extent to which the characters are confined to particular metamers or shared with others.[8]

Stamens often are replaced by petals, and petals by calyx-like or leaf-like organs, although the original derivation of the foliage leaves may have been from the pistils rather than from the stamens, if the primitive ancestor had the sexes in separate plants. Minute functionless metamers (staminodes and pistillodes) are of general occurrence where the plant sexes are separate, and have been taken as evidence that the primitive plant ancestors had bisexual, "perfect" flowers, but it is possible that the rudimentary floral organs are metaphanic carry-overs from the other sex, like the nipples of male mammals. The doctrine of rudiments being reduced from functional organs would not be required in such cases. Functional development of carry-overs is not precluded, but would not explain their occurrence in rudimentary form. A mechanical explanation may be found. as of echoes or mirror images.

Genetic Relation of Leaf Structure and Stem Structure

The double-deck papaya leaves are hardly to be interpreted as intermediates between forms of metamers previously existing, but rather as an addition or reduplication of metamer characters, which also may be said of the composite leaf-forms among the hickories and walnuts. A compound leaf is a compound metamer, built in sectional form, and to that extent is similar to a branch. That new sections can be added to an existing leaf-structure, is strikingly illustrated by the papaya variation, where additional petiole sections are provided which separate the reduplicated leaf-sections, thus completing the analogy with the formation of a branch.

In view of the specialized dimorphic branches which occur in cotton, coffee, cacao, and several other plants, it is hardly to be denied that approximations to leaf-forms might be reached through reduction of branches, though such specializations appear to be connected primarily with the flowering habits of the plants, rather than with vegetative

*For examples of chimeric metamers in almond flowers, with radial combinations of sepal and petal characters, see JOURNAL OF HEREDITY 17:423, 1926, Figures 14 and 15.

functions. A leaf-like character may be inferred from the temporary nature of the specialized branches of Castilla, Zizyphus, and Phyllanthus, but inflorescences as well as leaves are deciduous in most of the trees and woody plants. Some of the leaves that are considered as deciduous are not released at the base, but have a specialized articulation above the foot element, as occurs in plums, peaches and barberries, and in the coca shrub of Peru (Erythroxylon). In such cases the stipules remain with the persistent foot element of the leaf, only the blade-element being deciduous.

Even in groups where the pinnae of compound leaves appear to have originated as subdivisions of a primitive leaf blade, as in the Tree of Heaven (Ailanthus), a reduplication or carry-over of characters of the foot element may have occurred in building up the rachis, so that a structural analogy of leaf-sections and stem-sections may be recognized. Stipules are shown as rudiments on bud-scale leaves of Ailanthus, but are completely suppressed in the larger leaves, instead of being expanded into pinnae as in the walnut family. Reduplication of the foot element is indicated also in leaves that have both stipels and stipules, as in many leguminous plants. In the kudzu-bean (Pueraria) the stipules have developed nectaries while the stipels have remained simple.

Parallel variation would be admitted to account for superficial similarities of branch-forms and leaf-forms, but a true homology of structural correspondence would not be supposed to exist between a leaf-structure and a stem-structure. Goethe's original concept of homology referred to structural correspondence between diverse members of the same organism, and the secondary applications of homologies, to species and higher groups, are justified only to the extent that the primary meaning is recognized. Thus the metamer homologies are the standard for testing the group homologies, as based on community of descent.

A general tendency to the carry-over of stem-structures to leaf-structures may be inferred from the development of compound leaves in so many families of plants. The adaptive advantage of expanded leaves would seem to be limited to conditions of forest undergrowth where wind exposure is slight and competition for sunlight is severe. In some of the plant families a return to simple-leaved forms from ancestors with compound leaves is indicated, as in Citrus and Berberis. An extreme of adaptive adjustment is presented by desert conditions, where leaves not only become unnecessary but in many groups have been reduced to rudiments or entirely suppressed, as in many of the Cactaceae.

Sequence in Leaf Development

Differences in the sequence of development in compound leaves may be connected with the methods of derivation from simple leaves. An apical pinna that corresponds to the blade element of an original simple leaf, as in the walnut family, may be expected to complete its development from the bud in advance of the lower parts of the leaf, or at nearly the same time. On the other hand, a compound leaf derived in the manner suggested by the Carica variation would have the oldest section at the bottom of the series, and the newer sections above. Leaves with the original blade element at the top, and the middle sections intercalated, might be described as *mesoneotic*, while leaves with the original blade element remaining below and the terminal sections added above, could be described as *acroneotic*.

The methods of derivation of compound leaves may also effect the ar-

rangement of the pinnae. In leaves composed of reduplicated stipules the lower pinnae may be expected to stand in opposite pairs, while alternate pinnae may occur in leaves that are formed by gradual subdivision of a primary leaf-blade as in Ailanthus, or where pinnae are added above a primary leaf, as suggested by the Carica variation. If pinnae are added in opposite pairs, the absence of an unpaired terminal pinna would be explained.

Such inferences would need to be checked against the possibility of secondary modifications that would conceal the primitive arrangements of the pinnae. An original apical pinna might be suppressed in leaves that were evolved by intercalation of pinnae (mesoneotic), or a terminal pinna might become specialized and take a symmetrical form, even though derived originally as a lateral pinna. Differences in form and symmetry between terminal and lateral pinnae often are very pronounced, and such differences may be significant in tracing the evolution of leaf-forms.

Since the Carica family is not closely related to any other group of plants, there can be no assurance that similar variations occur in other groups or that similar courses of leaf evolution have been followed. But it is desirable to recognize the possibilities of structural modification that are inherent in the plant organization, in order that the extent of their occurrence may be determined. Goethe's basic conception of the plant organization should be utilized for a better understanding of morphology, evolution and heredity. The plant body is developed as a succession of different kinds of structural units, or metamers. Variations may be recognized in characters of metamers as well as in differences between plant individuals or between different species.

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The Chromosomal Determination of Sex

SEX DETERMINATION, *by* F. A. E. Crew, M. D., D. Sc., Ph. D., Professor of Anmial Genetics in the University of Edinburgh. 8vo. Five chapters. 137 pages. Price 3s. 6d. Methuen & Co., Ltd., London, 1933.

THIS little book (one of the Methuen Monographs on Biological Subjects) is a condensed survey of information on the chromosomal determination of sex. The subject is treated

with a breadth and thoroughness that one would scarcely expect to find in so small a volume. Despite the condensation, there are few omissions or ambiguities. An unusual proof-reading oversight appears in the glossary where it is stated four times that the Greek root *zygon* (yoke) means yolk—but probably no one will be misled.

The first chapter introduces the concept of protoplasm and cells, and then proceeds to a consideration of asexual and sexual reproduction, mitosis and meiosis, and the *Drosophila* and *Abraxas* types of chromosomal distribution. The second chapter provides a somewhat historical account of the cytological and genetic experiments and techniques which have led to our present knowledge of sex chromosomes and their behavior in different plant and animal groups. The third and fourth chapters treat of normal and artificial parthenogenesis and set forth current views on genic balance and intersexuality. The short fifth chapter is devoted to speculations concerning the evolution of the sex-determining mechanism, and a conclusion which is rather adequately expressed in the final sentence of the book. "It is enough for the present to state that, as far as is known, the sex-chromosome distributing mechanism is the sex-determining mechanism in all those forms in which such chromosomes exist, but in the case of many forms this mechanism can be overridden and the sex of the individual determined in other ways."

For the lay student the book provides a readable and authoritative introduction to the genetic aspects of sex. The general biologist and the professional geneticist will find in it interesting discussions of a number of moot questions—bimodal distribution of sperm cells, dimegaly in eggs, prezygotic effects of genes, gynandromorphism in birds, and other matters of physiologico-genetic interest.

A feature that will no doubt be welcomed by many readers is a clear exposition of Goldschmidt's views on sex determination in the gypsy moth, and a comparison of these views with those of Bridges. The author sees no necessarily fundamental incompatibility between the two points of view, and seems to look for their complete harmonization with further increase in knowledge. He is inclined to regard with favor the idea that gene *F* of Goldschmidt may impress on the cytoplasm of the oocyte a characteristic potentiality which will last through the whole period of development, even though the gene itself be lost from the egg during maturation.

The speculations in the last chapter reflect a growing tendency to inquire into the source and original nature of the gene itself. After citing Muller's suggestion that the bacteriophage may be a gene, the author indicates how, conceivably, "half-living chemical molecules suspended in water and enclosed in an oily film" might through fortuitous mutations have developed into self perpetuating aggregates with the potentiality of evolving gradually, by aid of natural selection, the structural and functional characteristics of chromosomes and cytoplasm. From the "original simple colloidal complex to the first and simplest unicellular organism known to the biologist is a step as vast as that which separates the latter and man." Whatever the real history of the origin of life may have been, it is significant that as time goes on speculations in regard to it can be based more and more on demonstrated facts.

The text is supplemented by a glossary of scientific terms with notes on their derivation, a bibliography of some 200 selected titles, and an author and a subject index.

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FINGER PRINTS OF CONJOINED TWINS

Differences in Gibb Twins and Their Genetic Significance

HAROLD CUMMINS and G. TYLER MAIRS*

THE birth of viable conjoined human twins is a rare event, but since these "Siamese" twins come to be widely exploited and seriously investigated by various observers it is surprising to find on record so little information concerning the features which are to be treated in this note. Dermatoglyphics, or the configurations of epidermal ridges on the digits, palms and soles, figure prominently in recent studies on twins, yet for conjoined twins the dermatoglyphic features remain almost unknown. In view of their important bearing on twin biology, as emphasized in the conflicting interpretations of the two writers (Reichle, Newman) who have dealt specifically with the problem of dermatoglyphics in conjoined twins, advantage should be taken of every opportunity to accumulate material which may throw light on the questions at issue. The purpose of the present note is primarily to make available a record of observations in a well known pair of such twins, Mary-Margaret Gibb, though we introduce some suggestions toward interpretation of the findings.

Finger prints of the Gibb twins were taken in the fall of 1931 by Mr. Charles O. Tittle.† At the same time he secured prints of a sister and both parents, thus making possible comparisons with these members of the family. We are grateful also to Mr. and Mrs. Gibb for their kind permission to use this material.

Mary-Margaret, who were born in May, 1912, apparently have the distinction of being the conjoined twins first subjected to critical dermatoglyphic study. The late Professor Wilder examined these twins when they were but a day or two old, and then, shortly before their second birthday, managed to obtain fair prints of all four soles. The attempts to make palm prints were not successful, though by direct observation it was made out that the four palms are essentially alike. Three of the soles correspond closely, while the fourth, the right foot of Mary, shows a marked unlikeness. No finger prints were obtained.

The Gibbs represent that type of conjoined twins known as *pygopagi*. They are united in the sacro-iliac region, not directly back-to-back but obliquely. The attitudes shown in Figure 9 are dependent on this oblique relationship at the juncture. The marked facial differences which are stressed by Newman as characteristic of conjoined twins are also apparent in Figure 9.

The Finger Print Records

We may now turn to the finger prints, first comparing them in the twins, their sister and parents, and then inquiring into the significance of the findings.

The five sets of prints are shown in Figures 10-11. Above each print is a notation recording certain characteristics of the pattern, entered in the following order: 1) *The type of pattern,* designated according to the familiar Galton-Henry classification, using the initial letters of the pattern names; 2) *The type of pattern,* designated according to the numerical classification of Mairs†; 3) *The ridge count,* which for the present use

*Tulane University, Department of Anatomy, and Finger Print Bureau of the City Magistrates' Courts, City of New York, respectively.

†Assistant Supervisor, Finger Print Bureau of the City Magistrates' Courts. We wish to acknowledge indebtedness to Mr. Tittle for placing the prints at our disposal, together with the photograph which is here reproduced.

is to be regarded as an index of pattern size, the significant size of patterns having two ridge counts (whorls) being indicated in the larger of the two figures; 4) *Index of pattern form,* a value showing the breadth-height ratio, (described in Cummins and Steggerda[5]); the larger the index, the broader is the pattern in relation to its height.

It may be of interest first to point out that the parents represent contrasting tendencies in finger-print characters. The mother's trend is toward reduction of patterns. Five of her ten digits bear arches (of a transitional type assigned to category No. 2 in Mairs' numerical classification) and five have ulnar loops. The father presents larger and more elaborate patterns, eight ulnar loops and two whorls, and it should be noted that five of the loops are akin to whorls in that they approach the configuration of central pockets. Mary has four whorls and six ulnar loops; Margaret has three whorls, two radial loops and five ulnars, one of the last approaching a central pocket. The sister, Dorothy, has one whorl and nine ulnar loops.

As a further aid to the comparison and contrast of qualitative finger-print characteristics the Mairs numerical method of classification is applied. This method employs integers as symbols of the fundamental type forms, with sub-classification of their varieties indicated in decimal fractions. The primary integer classification alone is listed here, and though the reader must be referred to the original account for complete explanation it should be understood that the basis of the scheme is the orderly series of relationships between the most highly "perfected" patterns (the alpha whorl of Mairs, type symbol 9) and patterns wholly devoid of characteristics found in these alpha whorls (the omega arch, type symbol 1). Four ranks of patterns linking 9 and 1 are recognized, and in the three highest the directions of pattern degeneration are symbolized by the use of even numbers for ulnarwise degeneration and odd numbers for radial (in patterns of the same morphological level). It is evident, then, that the six ranks of patterns represent a sequence of descriptive affinities, here translated simply into the numerical categories: 9 ——> 8 or 7 ——> 6 or 5 ——> 4 or 3 ——> 2 ——> 1.

With the significance of these numbers in mind, the following table may be scanned for resemblances and differences in the fundamental type forms of patterns, comparing digit with digit, hand with hand and individual with individual. The table adds emphasis to the statement below that the left hands of Mary-Margaret are more conspicuously different than the rights.

Mary	L. 6 7 6 8 4	R. 8 4 4 8 4
Margaret	L. 8 3 4 6 6	R. 8 3 4 8 4
Dorothy	L. 6 6 4 4 4	R. 8 4 4 4 4
Mother	L. 2 2 2 4 4	R. 2 4 2 4 4
Father	L. 4 6 8 6 4	R. 6 8 6 6 6

Attention may be turned next to a more exacting quantitative analysis of the patterns, based upon ridge counts as an index of pattern size and measurements of pattern form. The mother's tendency toward reduction of pattern size is indicated by an extremely low average ridge count of the ten digits, 2.6. The average ridge count of the ten patterns of the father is 18.7. Now turning to the conjoined twins, it is to be noted that the resemblance to the father, just as in the incidence of pattern types, is much closer than to the mother. Mary has an average ridge count of 15.3, and Margaret is essentially the same, 15.5. The separate sister, Dorothy, yields an average ridge count of 15.3. As to the index of pattern form (average of the ten measurements in each individual), Mary and Margaret conform closely, with respective averages of 70 and 71, their trend in this feature being perhaps not significantly different from the father (65) when it is considered that the determination is inexact. Dorothy, however, deviates sufficiently (with an average index of 80) to evidence a probably significant difference from Mary-Margaret and the father, perhaps showing the influence of the maternal tendencies (the mother having still broader, more depressed configurations, index 118).

THE TWINS AND THEIR MOTHER
Figure 9

Mary is on the left and Margaret on the right. Note the facial differences between them. Such differences are characteristic of conjoined twins in contrast to the often astonishing similarity between identical twins which are separate.

With regard to asymmetries, it is important to observe that both in Mary-Margaret and the Hilton twins (tabulated by Koch in her report of physical and mental measurements in this well-known example of "Siamese" twins) the collective differences are unequal bimanually. When the traits of all five fingers in each hand are considered collectively and subjected to homolateral comparisons (the right hand of one twin with the right of the other, and left with left) it is found that greater differences occur in the left hands of the twins than in the rights. Two examples of conjoined twins are obviously an insufficient basis for generalization, but the occurrence is nevertheless suggestive when it is recalled that in certain dermatoglyphic features left hands are the more variable.[4] In connection with bimanual inequalities in magnitude of variability it should be noted that the several digits are similarly unlike, as shown by numerous workers. The index finger, for one, may be regarded as a focus of high variability, hence it is not surprising to find in these Gibb twins a diversity among the patterns of the four index fingers, including the reversals of asymmetry which were formerly regarded as peculiarly significant in "identical" twins.

Finger Print Differences

It is demonstrated that Mary and Margaret display quite conspicuous differences in their finger prints, and attention may be called to like findings in the Hiltons. Reichle emphasizes differences in the palmar and plantar dermatoglyphics of several museum specimens of joined twins, and Newman in commenting on the subject remarks: "We see, then, that all observers of conjoined twins are more impressed by their differences than by their similarities." Being satisfied that finger-prints share with other features the expression of marked differences in conjoined twins, we may next inquire into the explanation of these differences, which have a special significance since conjoined twins are of the "identical" variety, arising from a single fertilized ovum.

Newman points out that the differences observed in conjoined twins are in accord with his theory of twinning, which is based on the essential postulate "that true monozygotic human twins [whether separate or conjoined] are the products of the division of a single bilateral embryo into two halves which if not separated, would form the right and left halves of a single individual . . . . But complete identity of the twin products of such a division is usually prevented by two factors: *a*, there may be a genetic bilateral asymmetry in the original zygote which would prevent the

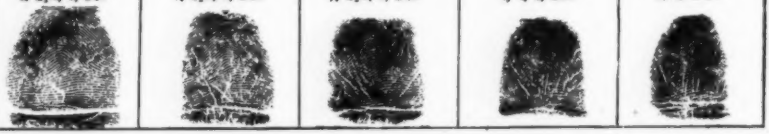
NAME Mrs. Margaret Gibb CLASSIFICATION 1 aUa / I aAa NO.

RIGHT HAND

Thumb	Fore Finger	Middle Finger	Ring Finger	Little Finger
A/2pu/0/200	U/4/4/90	A/2pu/0/160	U/4/8/77	U/4/7/57

LEFT HAND

Thumb	Fore Finger	Middle Finger	Ring Finger	Little Finger
A/2pu/0/167	A/2pu/0/140	A/2pu/0/140	U/4/3/100	U/4/4/50



NAME Mr. John Gibb CLASSIFICATION 19 0 / 1 U 0 21 NO.

RIGHT HAND

Thumb	Fore Finger	Middle Finger	Ring Finger	Little Finger
U(CP?)/6N(8N?)/ 20/70	W^{R}/8K/15-9/65	U/6N(4?)/15/56	U(CP?)/6N/23/50	U(CP?)/6N/22/54

LEFT HAND

Thumb	Fore Finger	Middle Finger	Ring Finger	Little Finger
U/4(6N?)/22/100	U(CP?)/6K/16/86	W^{U}/8K/17-11/41	U(CP?)/6N/19/63	U/4/18/65

NAME Miss Dorothy Gibb CLASSIFICATION 1 U 00 / 17 U 00 20 NO.

RIGHT HAND

Thumb	Fore Finger	Middle Finger	Ring Finger	Little Finger
TL^{U}/8K/16-14/68	U/4/12/108	U/4/11/71	U/4/16/83	U/4/20/68

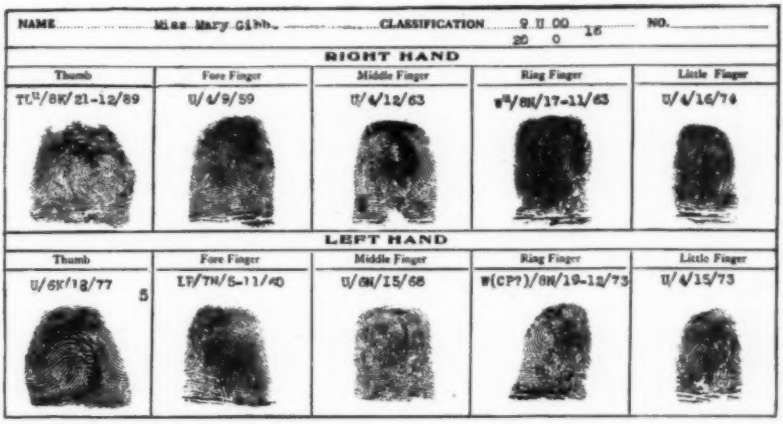
LEFT HAND

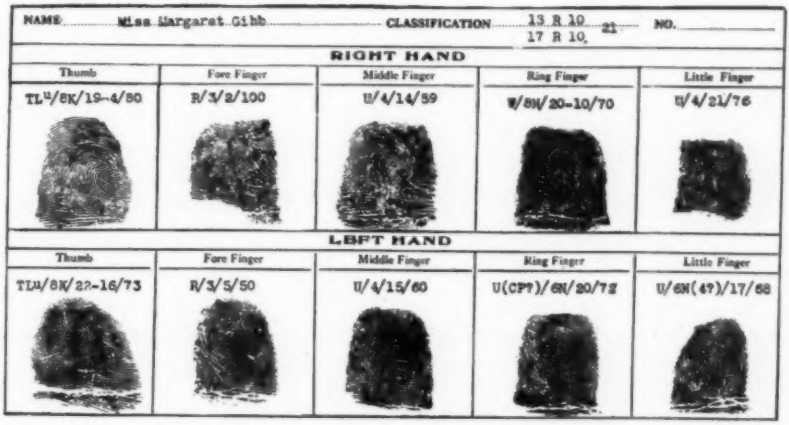
Thumb	Fore Finger	Middle Finger	Ring Finger	Little Finger
U/6K(4?)/22/95	U/6N/13/62	U/4/13/81	U/4/11/88	U/4/19/75

FINGER PRINTS OF PARENTS AND A SISTER

Figure 10

See legend on opposite page.





FINGERPRINTS OF MARY-MARGARET GIBB

Figure 11

Conspicuous differences in the finger print patterns are to be noted. It is the belief of the authors that these differences are to be accounted for by the disturbed developmental environment within the united embryos rather than because of delayed separation and disturbed "asymmetry mechanism" as postulated by Newman. Note also that indications of inheritance of finger print pattern are to be found in the greater resemblance of the prints of Mary-Margaret to the father than to the mother, suggesting a dominance of the father's finger print patterns. There is also a close resemblance between the thumbs of Dorothy, the separate sister, and Mary.

resultant products from the two halves being entirely identical; *b*, there is a progressive differentiation of the two sides of the body toward the mirror-image condition of the two body halves, which can be only partially recovered from by the embryo which has acquired the reversed asymmetry." It is when the twinning process occurs too late to admit complete separation that double monsters arise, and these "show profound asymmetry reversal in the median structures

of one component and a tendency for the more or less completely bilaterally paired structures of a component to be the same on both sides . . . ."

It is our belief, in agreement with Reichle, that there are still other factors, epigenetic or parakinetic in origin, which should be considered as sources of difference between the members of these twin pairs (and of separate twins as well). The mechanism conditioning finger-print traits is a multiple-factor complex,[1] operating at a relatively late period of the embryo (third and fourth months) and in a developmental medium which is so labile that germinally prospective traits may be fortuitously altered or suppressed.[2,3] In a single individual it is evident that the potencies of a germinal control for finger-print characters may not be actually expressed, since various circumstances affecting the growing embryo are capable of altering the medium of development of the dermatoglyphic features, thus producing novel configurations which would be unpredictable on the basis of genetic composition. Reichle and others have directed attention to corresponding sources of variation in separate single-ovum twins, associated with their intrauterine relations. It is to be expected that such influences are intensified in united twins, thus accounting for their heightened dissimilarity, more extreme differences being found in such pairs, according to Newman, than in the most unlike separate single-ovum twins.

Conjoined twins appear to be especially subject to modifications of the normal course of development, due to handicaps attendant upon the union of these "Siamese" twin embryos. Departures from the normal anatomy are frequently evident in one or both members of a pair, and no explanation of structural unlikeness of the members is complete if it neglects the factor of developmental handicap imposed by physical union. A famous instance of *pygopagi*, the Blazek Sisters, probably the most thoroughly investigated of all joined twins,[10] showed among other effects of their union spinal curvatures and in one member a leg of reduced size (5 cm. shorter). Included in Reichle's series of five specimens there are varieties which commonly exhibit a more profoundly imperfect morphogenesis. Even though the dermatoglyphic areas are definitively remote from the point of body union, and hands and feet usually free from signs of obvious abnormality, it must be remembered that the dermatoglyphics are highly sensitive indicators. It is apparent, then, that in the face of disturbing epigenetic influences neither the dermatoglyphic prospects of germinal composition nor the prospects of regulation by an asymmetry mechanism may be fully realized. Finger-print differences, together with unlikenesses in other features in twins such as Mary-Margaret, may represent simply mild expressions of fortuitous variation, variation which is carried to grotesquely abnormal extremes in the general anatomy of various types of double monsters. A collateral argument is presented under the next heading.

Twinned Bodies and Twinned Digits

In observing a wide range of examples of the twinning process one is bound eventually to reach a point of indecision as to just what it is that constitutes "a twin." Ordinary "identical" twins bear the twin relationship to each other on account of their common origin from a single fertilized ovum. Conjoined twins, exemplified by Mary-Margaret, likewise have such common origin, and the relationship is recognized as equivalent to that of separate identical twins. On the other hand, doubling may give rise to asymmetrical double monsters, and if the sequence of degrees of duplication is traced further it is seemingly justified to regard doublings of even minor parts as members of the same series. The subjective reaction of the observer may at first tend to erect a classification in which only the complete and nearly complete examples of doubling are regarded as twinning phenomena. Because there are two bodies, two bodies which are nearly

complete, or one body bearing a supernumerary head or other spectacular duplication the cases are considered twins. But in minor duplications, such as the production of extra digits, sight may be lost of the fact that they represent phases of a like doubling process. The point is emphasized because it is believed that the dermatoglyphics of "twinned digits" may be profitably considered in relation to those of twinned individuals.

In connection with another aspect of dermatoglyphic analysis Cummins published in 1926 the findings in twenty-six such digital couplets (pairs of "twinned digits"), and additional observations have been accumulated since that time. In some cases it is found that the patterns of the two digits are of the same general configuration, while in others they are unlike and even occasionally of markedly atypical form. There is no consistent relation of the asymmetries of the paired patterns. The duplicated digits may be ranged in a series in accordance with the degree of completeness of the supernumerary member and the structural relation of the two digits. The sequence indicates that unlikeness, both of configuration type and of asymmetry, may be directly correlated with the anatomical relations of the two digits. Patterns of similar configuration and asymmetry occur in the majority of instances where the supernumerary digit is completely developed and separate, while differences are invariable when the duplicated digit is structurally deficient or joined to its mate (syndactylous). If a situation so tangible as this exists in "twinned digits" it suggests that a similar explanation may apply to the differences in conjoined twins.

Newman emphasizes that a developmental distinction of conjoined twins, as contrasted with separate twins, is that the division of the embryonic rudiment occurs later. "Twinned digits" make their actual appearance as structural members still later in the history of the embryo than do separate twins, conjoined twins or any type of double monster. But whatever the history in time of digital duplications, it is quite evident that the immediate causation of pattern unlikenesses in digital couplets is not to be ascribed to late origin, but to the abnormal developmental environment of the integument clothing an imperfectly formed supernumerary digit or a fused (syndactylous) digital couplet. As stated above, we suggest that the differences observed in joined twins are likewise at least in part merely expressions of a disturbed developmental environment within the united embryos.

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(Another article by Reichle, dealing with Newman's criticism of his 1929 papers, and a reply to it by Newman appeared in the Journal of Heredity of January, 1934, too late to be discussed in the present note.)

ALCOHOL-TOLERANCE OF DROSOPHILA

An Instance of Adaptation to an Environment Lethal to Most Organisms

M. J. BROWN
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THE Drosophila or fruit fly has frequently been reported to grow on specimens used for laboratory study which had been preserved in alcohol or formalin. For example a statement comes from the University of Minnesota that Drosophila larvae were found growing among the cadavers used for medical study, and similarly at the University of Wyoming larvae were found on dogfish and a sparrow. The dogfish, which were preserved in formalin, had become exposed above the preserving fluid and it was on this exposed portion that the fly eggs had been deposited and hatched. The concentration of formalin used was not definitely known but it was reported to be strong enough to preserve the specimens. The sparrow had been preserved in alcohol, but again the concentration was unknown.

In looking over the literature on the food of Drosophila, Schultze reports, "In a shipment of heads of Herero- and Hottentotts from South Africa, which were preserved in formol it was found that they contained fly larvae, pupa and adult flies on top. They were identified as *Drosophlia rubrostriata*. Some pure formol was then added and it was found that they continued to grow." In the same paper Schultze states that other species of Drosophila have been reported to grow in plant tissues, mussel tissues, etc. He says the growth of Drosophila in formol is due to the presence of the formic acid which resembles the fermentative medium which is present in decaying fruits, upon which the flies thrive.

Because of such statements and the fact that these flies live about fermenting fruits which contain from five to ten per cent alcohol, the following experiments were performed to determine the exact concentration of formalin and alcohol upon which they were able to live.

A preliminary set of experiments was performed between January and May of 1932, then a recheck was made between October and December of 1933.

In the earlier part of the experiment an attempt was made to duplicate the conditions of the laboratory where the flies had been growing. The temperature of the laboratory was about twenty-four degrees C., with good lighting and a dry atmosphere, since the altitude of Laramie is 7,000 feet.

The preservatives used were commercial formalin (40%), 100% alcohol (methyl), and 95% ethyl alcohol. These stock solutions were not chemically pure solutions but were the grades ordinarily used as preservatives in the laboratory.

From these stock solutions different concentrations were prepared and placed on pieces of guinea pig meat in seventy-five cc. bottles. Small pieces of fresh meat, (parts of the viscera and muscles of the guinea pig) about two cm. in length, breadth and thickness were used and enough preservative to cover the meat completely. About twenty-four hours later, when the meat had been thoroughly preserved enough of the solution was removed to permit the exposure of the upper surface.

Some flies, *Drosophila amelophila*, Loew*, were then added to the bottles, which were stopped with cotton. Two or three flies of each sex were added. Duplicate bottles were prepared and one set was left exposed to the light in the laboratory and the other set was placed in a dark box. No difference, however, was noticed in these methods, consequently later containers were exposed to the environment of the laboratory, when not controlled in an incubator. Some bottles were also left open to permit access for the flies about the laboratory, but these results were negative.

The different percentage concentrations of the solutions used in this first experiment were as follows:

Formalin: 0.66, 1.33, 3.3, 6.6, 13.3, 20 and 26.6%.
Methyl alcohol: 1.3, 3.3 and 6.6%.
Ethyl alcohol: 3.3, 6.6, 13.3, 26.6, 33.3, 40, 46.6, 53.3 and 60%.

As a result it was found that *Drosophila ampelophila* did not live on animal matter which had been preserved in formalin with as high a concentration as 0.66 per cent; they did live on animal matter which had been preserved in methyl alcohol between the concentrations of 3.3 and 6.6 per cent; and they lived on animal matter which had been preserved in ethyl alcohol between the concentrations of 6.6 and 13.3 per cent.

Further experiments were then carried on with the following medium (Bridges' formula):

40 grams agar agar
200 grams corn meal
140 cc. Karo corn syrup
140 cc. Bre'r Rabbit molasses
2,000 cc. water
2-3 drops of a small portion of yeast cake dissolved in water, added when cool.

This is commonly used in culturing Drosophila flies. To each bottle was added twenty cc. of the medium and while yet warm the proper number of cc. of preservative of known concentration was added to make the desired concentration of solution. This was mixed thoroughly with the medium, a small strip of filter paper was added for the larvae to pupate upon, and when cool the flies were added.

The different concentrations of solutions used at this time were as follows:

Formalin: 0.76, 0.16, 0.33, 0.5, 0.66, 0.83, 2.44, 3.3 and 4.16%.
Methyl alcohol: 0.83, 1.66, 2.5, 3*, 4.16, 5, 6.6, 8.33*, 10*, 13.3*, 16.6, 26.6 and 33.3%.
Ethyl alcohol: 0.83, 1.66, 2.46*, 3.3, 5, 6.6, 8.33, 10, 10.6*, 11.66, 13.3*, 15, 15.6*, 15.83, 16.6*, 20.04, 22.31, 23.3*, 26.6*, 30*, 31.6*, 33.3*, 41.46 and 50.13%.

(In those cases checked * the flies were transferred from a culture which had been reared on a medium of lower concentration, while in all other cases they were transferred from a stock culture which had been reared on the plain agar medium.)

It was found in this experiment that *Drosophila ampelophila* will grow on an agar medium diluted with formalin to a concentration of 0.076% but not of a higher concentration; they will grow on an agar medium diluted with methyl alcohol to a concentration between 0.83 and 13.3%; and they will grow on an agar medium diluted with ethyl alcohol of a concentration between 0.83 and 33.3%.

Since temperature was a variable factor in these experiments it was thought advisable to recheck the entire experiment under controlled temperature conditions. This was partly done during December of 1932 and then again a double check was made during 1934. In 1932 the cultures were kept in an incubator at an average temperature of 24° C. (there was a variation between 23 and 26° C.) and in 1933 at a temperature of 22° C. (again there was a variation of one

*Determination made by Dr. J. M. Aldrich of the U. S. National Museum.

In addition the writer wishes to express her appreciation to H. Gilbert, research apiculturist of the University of Wyoming for the use of the incubator and to R. Honass, research parasitologist for aid in the preparation of some of the media and solutions and for the pH determinations.

degree above or below this average).

The data obtained in these experiments were very similar to those of the earlier experiments. The extremes of concentrations used in 1933, in which the flies lived (by this is meant a second generation of flies was produced) was for the formalin, 0.05%; for methyl alcohol, 1 to 4%; and for ethyl alcohol, 0.66 to 30%.

The lethal point for methyl alcohol is much lower than that in the previous experiments but otherwise the results are consistant, and one can conclude that *Drosophila ampelophila* will not tolerate formalin in any high degree, and it is probable, when it has been used as a preservative on laboratory specimens, upon which Drosophila have been found growing it has been of a very low concentration: they have a high tolerance for ethyl alcohol and will grow in low concentration of methyl alcohol.

An attempt was also made to determine the pH of the media after the experiments had been conducted in the last instance, to see if this might have been a variable factor. The pH for the formalin media was found to be 4.0 (one bottle was tested); for methyl alcohol the average was 4.09 (7 bottles were tested); for ethyl alcohol 3.63 (11 bottles were tested); and for the controls (5 bottles were tested), it was 4.08. These figures then indicate that the pH of the methyl alcohol medium is more nearly the normal condition but it is not thought advisable to draw any definite conclusion with respect to the influence of the pH upon the results obtained in this experiment.

Yellow Fat in Sheep

PROFESSOR MOHR, when recently in this country to deliver a course of lectures on human heredity at the Harvard Medical School, visited my laboratory and was shown some of our results on the study of the inheritance of yellow fat in rabbits. He remarked, at the time, that a similar variation occurred in sheep in Iceland. After his return to Oslo he sent me the communication which follows. This indicates clearly that the yellow fat mutation which occurs among sheep in Iceland—but, so far as my information goes, is unknown elsewhere—is a simple recessive character in inheritance. It doubtless arose there, and though objectionable from a market standpoint, continues to recur whenever a mating occurs between parents which, though themselves having white fat, yet transmit the yellow character as a recessive.

In rabbits the gene for yellow fat is genetically linked with the genes for albinism and for brown pigmentation, as first shown by M. S. Pease, and substantiated by my own observations. It would be interesting to know whether in sheep yellow fat is linked with any of the mutations for distinctive colors or color patterns.

W. E. CASTLE.

Oslo, February 22, 1934.

My dear Professor Castle:

You remember, perhaps, that I promised to try to obtain some information on the yellow fat character in sheep. Recently I wrote to Mr. Páll Zóphóniasson, Búnadarfelag Islands, Reykjavik, Iceland, and he sends me the following information which he places at your disposal. The yellow fat character prevents the meat from being sold in the market.

In Iceland the sheep have for a long time been crossbred—fear of inbreeding. The owners leave the ewes and rams out in the fields, so it is very difficult or impossible to obtain pedigree data.

Nevertheless the following evidence is interesting enough.

Case 1. In 1928 Mr. Z- visited a farm, Esphof, where a number of "yellow" individuals had occurred. It turned out that seven years ago a

ram had been bought from a distant farm, and yellow individuals did not appear unless both their mother and father might descend from the ram mentioned. At the advice of Mr. Z- the farmer bought a new unrelated ram, and then no more yellow individuals appeared until last year, when he got three yellows. But in this case he had used rams that were bred on his own farm. Later Mr. Z- has visited the farm from which the first ram had been bought. At this farm yellow lambs had appeared occasionally for many years.

Case 2. (Very similar to Case 1.) Yellow appeared at the farm Kambur, among the descendants of a ram bought from a farm where yellow lambs occurred very frequently. Mr. Z- has later been able to demonstrate that 7 rams from the farm Kambur in matings to their own daughters have given yellow.

Case 3. At the farm Storngrof yellow lambs were of frequent occurrence. In 1920 15 lambs out of 120 were yellow. This year two rams were used that were brothers to most of the ewes. In 1931 the rams were, at the suggestion of Mr. Z-, replaced by 2 unrelated rams from another farm where inbreeding had been applied to some extent. Since then no yellows have appeared at Storngrof.

Case 4. At Hafsteinsstativ a ram was bought from Storngrof in 1924, who was father to most of the lambs bred at H- during the following years. In 1927 the first yellows appeared, and last fall "more than one quarter" of the lambs were yellow.

Mr. Z- tells me that he knows of 9 additional cases which in the main respects resemble Case 1.

As you see, the above evidence indicates that yellow in sheep is due to an ordinary recessive.

Yours very sincerely,

OTTO LOUIS MOHR.

What Every Mother Knows

THE FIRST TWO YEARS. A study of twenty-five babies, *by* MARY M. SHIRLEY. Vol. II. Intellectual Development. Vol. III. Personality Manifestations. Price, $3.00 and $2.50, respectively. The University of Minnesota Press, 1933.

THESE two books tell the story of the study of twenty-five children through the first two years of physical, and the first four years of mental development. A psychologist should have reviewed these books, for it takes a psychologist to enthuse properly over the psychological methods. For one who has raised three children of her own, who knows how seldom the infant responds with what it is capable of doing in the time allotted by the adult for the performance of the reaction, the elaborate tables of percentage scores, carried into decimal places, grow wearisome. Thus on page 145 of volume II is a table showing the percentage of babies distracted during a caliper reaching test. On page 176 of the same volume is a table showing "rank order correlations between total scores on developmental tests at different age levels." I am a bit vague as to what the table was designed to show, but have a feeling that in non-psychological language it was meant to show whether or not babies were consistent in their development. At all events, one finds not only the correlations but the probable errors worked out, and sometimes the probable errors were five times the value of the correlations themselves! Not being a mathematician, I would like to know just what value a correlation has when its probable error is five times as great.

The whole of the second volume would have been more acceptable, at least from the non-psychological reader's point of view, if the policy followed in the latter half of the third volume had been adopted; that is, if the method had been more a descrip-

tive one, and less mathematical. When one reads that a certain percentage of the babies tilted a bell and attempted to drink out of it, instead of ringing it, should one conclude that these babies failed to make the highest score, or that they should be credited with an extra mark for having perceived the similarity between the bell and the drinking glass? Chewing reactions are mentioned, and the average age, at which babies stopped chewing the toy, and played with it as the adult would expect, is worked out. I gather from the context that chewing is an "escape reaction"; the baby chews as a means of escaping from the task set it by the examiner. I am inclined to think that chewing can be correlated with something far more tangible than the age at which the baby is able to play appropriately and so ceases to use escape reactions from unpleasant situations; it is very definitely correlated with such a prosaic and unpsychological act as cutting one's teeth. A baby chews not to escape a difficult situation, but to relieve the ache in its gums.

The conclusions in volume II are for the most part what any intelligent person would draw from general experience, without two years of psychological tests to confirm their ideas. For example, "Behavior development in infancy always proceeds in harmony with or in conformity to biological laws of development." It is hard for behavior in infancy to proceed in any other way, inasmuch as it is dependent upon biological laws. Were the two in discord, then we would either have misstated the biological laws or mis-interpreted the behavior development. It is much like the physiologist who was astonished to find that the oxyhemoglobin curve of fishes was so different from that of mammals, and was designed especially to utilize oxygen at the low pressure at which it was dissolved in water. Far from this being astonishing, it would have been unbelievable that the oxyhemoglobin dissociation curve of fishes' blood was any other than that designed to take oxygen up at low pressures. The fish would have died out long ago had it been otherwise.

Another conclusion that could have been made by even a casual observer of babies is the following: "Development in babyhood proceeds by the differentiation of specific acts out of mass activity, and by the emergence of new items of behavior as well as by the improvement in behavior after it appears."

Babies Are Persons

Volume III was more interesting, although here some of the graphs which appear like a series of inverted skyscrapers, and some of the tables dealing with personality trends, attain to a mathematical precision which leaves the psychological layman wondering just how they do it. Again conclusions are reached that the intelligent mother knew long before. Thus they find that personality exists in babyhood. Well for the psychologists that they reached this conclusion; otherwise they would have conflicted with a mass of human experience that is overwhelming. Also "The correlations cited above suggest that some babies were placid, others irritable." It does not take a set of correlation coefficients to tell us that. They go on to say that babies differ in their personalities. I believe that it is only psychologists of a certain class that have ever believed that babies were a handful of plastic clay, waiting for the environment to mold them.

But the conclusion which is really worth while, one which the student of inheritance reached long ago, but which having been reached by one of their own ilk, may induce psychologists to believe in it more heartily is the following: "The evidence marshalled in this study is strongly on the side of innate differences in personality. The early appearance, pervasive nature and relative stability and permanence of personality traits, their consistent pattern and their harmony with familial

traits, all point to a hereditary basis. To be sure these results cannot be interpreted as conclusive evidence that personality potentials are laid down in the genes. But they do indicate that personality has its origin and physiological basis in the structure and organization of the nervous system, and of the physico-chemical constitution of the body as a whole." With this sane conclusion, sane people will agree. Some of us may go further and state that the structure of the nervous system, and the physico-chemical constitution of the body upon which personality rests are inherited factors, dependent upon chemical entities inherited in the germ plasm. This paragraph to some extent redeems the books from the charge laid against them, that they told us only what we knew. It tells us what some psychologists did not always know.

To the psychologist who feels that a personality can be dissected with the same mathematical precision that the nerves and vessels in a cadaver can be laid bare, these volumes will no doubt be of inestimable value. To such a one, I recommend them heartily. To the intelligent mother or observer of young children at close range, there is little information which was not already in one's possession. True, the mother may not have known that her infant would reach for a swinging tape in preference to a brightly colored ball, or that it would prefer satin to fur, but inasmuch as we must await the further enlightening touch of the psychologist to unravel the significance of such choices, the mother will go on believing just as she has always believed, namely that some babies are intelligent and that some are not; that some may respond to psychological tests with a high score, yet not be as intelligent as some of those with a lower score; that some children seek for the logical reasons behind these tests even at a relatively early age, and finding none sometimes, they fail to perform the test. Having studied three babies intensively, I am moved to paraphrase the immortal William and say to the psychologist, who attempts to encompass a baby's psychology in diagrams and percentages: "There are more things in a baby's intellectual make-up, than are dreamt of in your psychology."

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Fundamentals of Personality

THE PHYSICAL BASIS OF PERSONALITY, *by* Charles R. Stockard, M. D., Professor of Anatomy. Pp. 320. 16 Chapters. 73 illustrations. Price, $3.50. W. W. Norton & Company, New York, 1931.

FOR some years British scientists have been sufficiently emancipated to recognize their duty towards the laity. Whenever one of them sees an opportunity to present in a readable and stimulating manner a group of scientific facts sufficiently important to provide a contribution to lay education, he does so. Eddington, J. B. S. Haldane, Huxley and others have clarified their own thinking and have served mankind on many occasions in this way.

In our own country, laboring under teutonic self-appreciation of the profundity of technical scientific information, we have not yet reached such a liberal attitude. There is still apt to be loss of caste and a little sorrowful wagging of the academic head when a research worker writes interestingly and in a popular vein.

Among those who have had sufficient courage to defy convention in this respect no one is any better fitted than the author of *The Physical Basis of Personality*. Through out his scientific career Stockard has never lost sight of his duty as a teacher. Whenever he has synthesized a group of experimental data to

form a philosophical approach to a broad problem he has presented his ideas in a highly stimulating form. The volume under consideration is no exception to this general statement.

After a brief introductory chapter on the aspects of personality, the reader is shown how Nature provides for regulating the environment under which development of the individual takes place. Against this point of view is balanced the constitution or biological nature of the germ cell on which the environment must operate. A special chapter is concerned with the genes—or units of heredity—which serve to give to the germ cell such definiteness as it may possess. This subject is then amplified by a consideration of the nature of mutations which may alter the constitution of the gene. By the logical development of these topics the first hundred pages provide the reader with an adequate biological foundation on which he can erect a superstructure of information concerning the interaction of germ cell and environment resulting in the development of an individual.

The first phase of this process is naturally that which concerns itself with the embryonic life of the organism. A general discussion of the subject is followed in turn by a more detailed treatment of critical moments during early individual development and of mutation and character changes in the cells of the embryonic body.

Following these topics there is given a chapter on qualitative differences among children of the same parents. This discussion brings out clearly the basic differences between the experimental biologist and the behaviorist who ignores evidence which experience constantly provides.

From this point is developed in a series of most aborbing chapters the main activating principle of Stockard's thory—namely the importance of endocrine glands in determining personality.

A chapter on experimental transplantation of organs and parts of individuals to the bodies of others and on the uniting of entire individuals brings out the influence of the gonads and the discovery of Spemann and his associates of "organizers" in the developing organism. Conservatism and frank recognition of what we do not know as well as what we do, characterize the treatment of this topic.

The importance of the gonads is again emphasized in more detail in a chapter on periodic changes in personality. This naturally leads to a consideration of exaggerated deviations from racial type. The importance of hereditary gland defects in producing dwarfs and giants in both dogs and in man is discussed. In support of this point many of the more striking results of Stockard's experimental work in crossing various widely different breeds of dogs is cited in some detail. Using this material as an example, the subject of inheritance of form as related to personality is considered. Adequate black and white illustrations serve to bring out the various points.

In conclusion there is presented a general discussion of variation and balance in normal individuals and of the normal types of structure and personality.

At any time a book like Stockard's would be a welcome addition to the scientific background of all intelligent laymen. At present, however, it is peculiarly valuable. With the widespread and growing trend towards a more progressive and fundamental conception of our duty in recognizing and utilizing human differences in education the information contained in this book should be an essential part of the mental equipment of all who come in contact with educational institutions or programs.

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Jackson Memorial Laboratory

THE USE OF THE GREENHOUSE IN SORGHUM BREEDING

JOHN H. MARTIN
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SEVERAL plant breeders have grown sorghums* in a greenhouse during the winter to obtain seed, make crosses, or study plant characters in the seedling stage. [2,7,9,10] The advantages of a greenhouse in plant breeding are the same in general for sorghums as for other cereal crops, but certain vegetative habits of sorghum plants add materially to the usual advantages. The chief aid of a greenhouse in breeding sorghums is the speeding up of the program by growing a generation during the winter. The need or desire for a specific cross frequently does not occur to an investigator until the crop is mature and the season too far advanced for making crosses in the field. Crosses then can be made in a greenhouse in time to grow the F_1 generation in the field the following season. Indeed, during the winter and spring of 1930-31, the writer made a cross, planted the crossed seeds, and grew the F_1 plants to maturity in the greenhouse in time for planting the F_2 seed in the field.

Two varieties frequently bloom at different times under field conditions. Even tillers and branches that bloom later than the heads on the main stalks may not bloom at the proper time for crossing, although it often is possible to use the late heads of early varieties for crossing with the main heads of late varieties where the late heads are not killed by frost before the seeds mature. In a greenhouse, however, sorghums can be made to bloom throughout the year and crosses obtained at will.

Crossing sorghums in the field is inconvenient and difficult during windy or rainy weather. If the crosses are made just preceding a rainy period, there is considerable danger of the seeds molding in the bags used to exclude foreign pollen. In the greenhouse the weather is not a factor.

The special advantages of the sorghums as a greenhouse crop are that they need not be planted each season, that they can be propagated vegetatively, that plant material in all stages of growth is available throughout the year, and that crossing can be done at the convenience of the investigator.

The sorghums are regarded as annual plants but, where the temperature remains above freezing and moisture is available, the plants continue growth and thus live as perennials. Second (ratoon) crops of sorghums have been obtained in the field in this country[1,4] and in Australia[8] from tillers developed after the usual crop was harvested. In Figure 12*A* are shown some plants of Dwarf Freed sorgo in the greenhouse at Arlington Farm, Rosslyn, Va., near Washington, D. C. The seeds were planted December 6, 1927, and the photograph taken July 13, 1931. The plants are as large and vigorous as they were during the first season.

A sorghum plant usually develops 7 to 10 tillers if time and growing conditions permit (Figure 12*B*). Frequently the panicles on the tillers are only slightly later than those on the main stalk, but sometimes the tillers do not develop until the main heads are mature. The tillers develop from buds in the crown of the plant (Figure 12*C*). The lower tiller buds

**Holcus sorghum* L., *Sorghum vulgare* Pers., *Andropogon sorghum* Brot.

SORGHUM AS A PERENNIAL

Figure 12

Above is shown at *A* a group of plants of dwarf Freed sorgo after 43 months' growth in the greenhouse. At *B*, a Feterita plant with seven tillers, at *C*, a black hull Kafir plant with tiller buds and young tillers growing from the crown of an older plant. These can be separated and grown as separate plants. At *D*, are shown Feterita plants propagated vegetatively. The plants at the left and center were grown from branches having aerial roots. The plant at the right is a transplanted tiller from the plant at the left. In connection with the patenting of new varieties this technique may have interesting implications because asexually reproduced plants can be patented while sexually reproduced plants cannot. Under normal conditions a new variety of sorghum would not be patentable but under greenhouse conditions where it is propagated vegetatively it appears that a new form would be eligible to patent protection.

develop first and, if the plant is not killed by frost, the buds in the crown may continue to develop tillers until the upper bud has formed a stalk. Each tiller develops a root system and can live independently of the main stalk. The tillers do not develop, however, unless there is ample moisture and plant food for both the older growing stalks and the young tillers. Each tiller also forms crown buds which later may produce secondary tillers. By such repeated tillering the sorghum plants may continue to grow for indefinite periods. Each tiller necessarily forms its crown at a higher level than that of the preceding tiller. The plants shown in Figure 12*A* were forming crowns and roots about three inches above the surface of the soil after three years of growth, but again assumed normal subterranean tillering when four inches of soil was placed around the plants.

The following five varieties have been kept growing continuously for 6½ years in the Arlington greenhouse: Dwarf Freed sorgo, Dwarf hegari, Standard feterita, Dwarf Yellow milo, and Reed kafir. Other varieties, including Leoti Red sorgo, Beaver milo, Sunrise kafir, Sharon kafir, Shallu, Black Spanish broomcorn, and two varieties of kaoliang have been kept growing continuously in the same greenhouse for two or more years. These varieties represent widely divergent types of sorghums. All cultivated varieties of sorghums should behave more or less similarly.

When a panicle has about reached maturity a branch develops from a bud in the axil of the second leaf at the second node below the peduncle, if conditions are favorable for continued growth. These branches (or sideshoots) consist of several internodes and produce small heads which bloom and produce normal seed. The branches may be regarded as miniature stalks[3], capable of developing

AERIAL ROOTS AND BRANCHES
Figure 13

At the left are shown branches of a stalk of Brown Kaoliang forming aerial roots. These rooted nodes can be separated and grown as new plants. At the right is a stalk of Reed Kafir with leaf sheaths removed to show branches and branch buds, the upper buds develop first. These branches are essentially miniature stalks capable of developing roots and tillers.

roots and tillers. The branches produce fewer leaves and nodes than the main stalks. Immediately following the development of this upper branch, branches begin developing at the lower nodes of the stalk in consecutive downward order (Figure 13). Most sorghum stalks can thus develop 6 to 10 branches if time and growing conditions permit. The development of all the branches on a given stalk may require several months, but in some cases all the branches develop shortly after the main head has bloomed. As soon as any portion of a stalk above a growing branch has reached full maturity it dies and dries.

Sometimes, under moist conditions, the branches develop aerial roots at the base. Figure 13 shows a decumbent stalk of Brown kaoliang in the Arlington greenhouse which developed roots on four branches. None of these roots was in contact with the soil. The branches which form roots can be cut off and planted[5,6]. The left and center plants in Figure 12*D* were propagated in this way by the writer. In 1930 also plants were grown from transplanted rooted branches in a greenhouse at the Branch Experiment Station at Fort Hays, Kansas, by Mr. A. F. Swanson. The plant at the right in Figure 12*D* is from a tiller which had developed roots and then was separated from the plant at the left. It is thus possible to propagate sorghum plants vegetatively from either branches or tillers and so continue lines asexually.

Stalks in all stages of growth, as shown in Figure 12*A*, are present at all times when tillers and branches are developing continuously throughout the season. Mature heads and seed, heads in various stages of flowering and fruiting, and young stalks which have not yet formed heads can be observed at almost any time throughout the year. It usually is possible to find panicles in the greenhouse in the proper stage for crossing, regardless of the relative maturity of the two varieties to be crossed.

The best conditions for growing sorghums in the greenhouse have not yet been fully determined. The growth and development is much better during the longer and warmer days of late spring and summer than during the winter. Normal-appearing plants with well-developed heads have been grown in the greenhouse when the temperature was maintained at 85°F. or higher and artificial light was supplied for several hours during each evening after the plants had reached an average height of six inches. Slower and more limited growth is obtained when the temperature is not above 75° to 80° F., and the greenhouse plants are likely to be stunted under such conditions.

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A Glossary Of Genetic Terms

GENETICS has developed so rapidly that many terms in common use in genetic literature are not yet incorporated in the dictionaries. Many people who are interested in heredity are bothered by such words, for which no definition can conveniently be found. For this reason, it is proposed to publish occasionally a glossary of terms which would not be readily understood and which are not to be found except in new unabridged dictionaries. It is realized that these definitions will probably not meet with universal approval and comments and suggestions will be welcomed.

BACKCROSS—Cross of a hybrid to one of the parental forms.

BIMODAL—A frequency curve characterized by two "peaks."

BLENDING INHERITANCE—Inheritance in which dominance and monohybrid segregation are lacking. Genetic and biometrical methods have shown this is due, in many cases at least, to multiple factors independently inherited.

CHARACTER (a contraction of characteristic)—A term used, often rather vaguely, to designate any form, function, or feature of an organism. The Mendelian characters of genetics represent the end-products of development in which a definite gene, or genes, have a decisive effect. "The constant and unchanging thing, therefore, is the factor (gene) itself rather than the character, and the unity which Mendel observed lies rather in this underlying factor than in the visible, and perhaps variable, character which it produces."—Sinnott and Dunn.

DOMINANT—A character possessed by one of the parents of a hybrid, which appears in the hybrid to the exclusion of the contrasted character from the other parent (the recessive). Thus in a cross of green- and yellow-seeded peas the first generation has yellow seeds. Yellow is dominant and green is recessive, being transmitted but not appearing in the presence of the factor for yellow.

FACTOR—Same as *Gene*.

F_1—(Pronounced eff-one). The first filial generation. The offspring of a given mating.

F_2—The second filial generation. Produced by intercrossing or self-fertilizing the F_1. The inbred grandchildren of a given mating.

GAMETE—A reproductive cell of either sex; e. g. sperm or ovum.

GENE—(1) The unit of inheritance, which is transmitted in the germ cells, and which by interaction with the genic and cytoplasmic complex controls the development of a character. The genes are arranged linearly in the chromosomes. (2) "The physical basis of heredity"—or more figuratively, the atom of the genetic molecule.

GYNANDROMORPH—An individual of which one side (or part) of the body is female in constitution, and the other side (or the remaining part) is male.

HETEROZYGOUS—Containing both genes of an allelomorphic pair, or two genes of an allelomorphic series. Heterozygous individuals generally resemble the individuals homozygous for the dominant character, but they transmit the recessive to half their offspring.

HOMOZYGOUS—(1) An organism formed by like germ cells; (2) An organism is said to be homozygous for a given character when all the germ cells transmit identical genes for this character. This is the most frequently used meaning of the term.

MEIOSIS—The reduction divisions preceding the formation of gametes, in which the chromosome pairs separate, and the chromosome number is reduced to half the somatic number.

MONOZYGOTIC—Originating from a single fertilized egg cell, which in the course of subsequent development has given rise (by fission) to two or more individuals. Twins (or triplets, etc.) of such origin are, barring mutations, genetically identical.

MULTIPLE FACTORS—In the expression of some characters more than two genes are necessary. Such cumulative or cooperative genes are called multiple factors. See also *Blending inheritance*.

MUTATION—Where a heritable variation begins. A sudden variation in an inherited character.

PARTHENOGENESIS—The development of a new individual from a germ cell without fertilization.

POLYPLOID—Normal body cells of the higher plants and animals have two sets of chromosomes (see *Diploid*). Polyploids are forms having three or more of these basic chromosome sets.

RECESSIVE—See *Dominant*.

SEGREGATION—Separation of allelomorphic genes at meiosis.

SOMATIC—Referring to body tissues; having two sets of chromosomes, one set normally coming from the female parent and one from the male; as contrasted with germ cells having a single set of chromosomes.

TRIPLOID—An organism characterized by having three times the reduced primary chromosome number.

ZYGOTE—An organism produced by the union of two germ cells.

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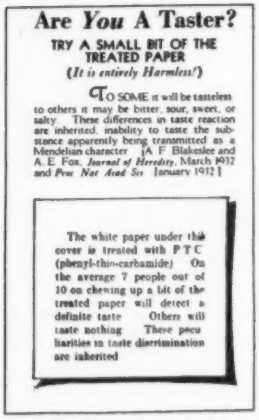
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